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TABLES OF SYMMETRIC FUNCTIONS FOR STATISTICAL PURPOSES

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SUMMARY

Symmetric functions have occupied a prominent place in the statistical theories.

In Statistics, symmetric functions are defined for n Variates and Moments are connected with the power-sum, symmetric functions S_r's by $n\mu'_r = S_r$, where μ'_r is the r-th moment of the n Variates with respect to the origin from which they are measured.

Considering the importance of symmetric functions, tables have been constructed, expressing Monomial Symmetric functions in terms of S_r's, by O' Toole, Sukhatme and Ziaud-Din.

In this paper tables of weights 7, 8 and 9 are given. Differential Operators and the characters of the Symmetric group have been used for their formation.

1. Recently symmetric functions have played an important part in the Mathematical theory of Statistics, and researches are being carried out on symmetric functions in connection with statistics. The symmetric functions are defined for n Variates $x_1, x_2, \ldots xn$ (which are of the serial distribution type but not necessarily integers) and Moments are connected with the power-sum symmetric functions S_r's by $n\mu' r = Sr$ where $\mu' r$ is the r-th moment of the n Variates with respect to the origin from which they are measured. If the origin is at the Arithmetic Mean of the n Variates, then $n\mu r = Sr$.

Considering the importance of symmetric functions in statistical computations, O' Toole (3) has expressed the monomial symmetric functions up to weight 6, as function of S_r's with the help of Differential Operators. The tables are also

of great use in the theory of symmetric functions and other branches of mathematics. Tables of weights 7, 8 and 9 have been constructed by the author and are given in this paper. Tables of weight 7 and 8 have also been worked out by Sukhatme (4), following a different method.

2. The following operational formula (5*i*), has been used in expressing the symmetric functions in terms of S*r*'s.

$$r!\,Q_r = \sum \frac{r!\; q_l^{\,a}\; q_m^{\,b} \ldots}{a!\qquad b! \ldots}$$

where

$$a\,l + b\,m + \ldots = r$$

$$qr = \frac{d}{d\,Sr},$$

$$Q_\lambda \left(p_1^{\lambda} p_2^{\mu} \ldots \right) = \left(p_1^{\lambda-1} p_2^{\mu} \ldots \right)$$

$r!\,Q_r$ can also be easily determined in terms of qr's from the tables of group characters thus:- Multiply each element in row of $[r]$ by the corresponding orders and by the product of the integers occurring in the corresponding classes, regarding the class as the indices of qr's, such that $1^3\,2^3 \equiv q_1^{\,3}\,q_2^{\,3}$, etc. Tables of group characters (See references 1, 2 and 5) are available up to degree 13.

3. The general procedure of working is indicated as follows. For the 9th degree assume the symmetric function $(f) = a_1 s_1^{\,9} + a_2 s_1^{\,7} s_2 + \ldots, \; a_{30} s_9$. Operate, (f) by $Q_1, Q_2, Q_3, \ldots$, and S*r*'s by the equivalents of $Q_1, Q_2, \ldots$ in terms of qr's. The unknown constants will be determined keeping in view the known tables of weights 8, 7, 6, . . . Thus the expansions of required symmetric functions in terms of power-sums, will be obtained. Some operations are, in general sufficient, but to ensure accuracy a good many have been tried

The well-known algebraic relations

$$\sum x_1^{\alpha} x_2^{\beta} x_3^{\gamma} = S_\alpha S_\beta S_\gamma - S_{\alpha+\beta} S_\gamma - S_{\beta+\gamma} S_\alpha - S_{\alpha+\gamma} S_\beta + 2 S_{\alpha+\beta+\gamma}$$

for α, β, γ (all different or equal to one another) serve as a check for some terms

The tables of degrees 7 (partitions 15), 8 (partitions 22) and 9 (partitions 30) thus constructed are given below.

The expansions of symmetric functions in S*r*'s can at once be written in full from the tables, for example, the expansion of (52^2) from the 9th table, is clearly

$$(52^2) = \tfrac{1}{2}\{S^2{}_2\, S_5 - 2S_2S_7 - S_4S_5 + 2S_9\}.$$

TABLE OF DEGREE 7

Indices of S_r's, *i.e.*, S_1^7 etc.		1^7	$1^5 2$	$1^4 3$	$1^3 4$	$1^3 2^2$	$1^2 23$	$1^2 5$	16	124	12^3	13^2	25	$2^2 3$	34	7
Symmetric Functions	Common Factors															
(7)																1
(61)									1							−1
(52)													1			−1
(51^2)	$\frac{1}{2}$							1	−2				−1			2
(43)															1	−1
(421)									−1	1			−1		−1	2
(3^21)	$\frac{1}{2}$								−1			1			−2	2
(41^3)	$\frac{1}{6}$				1			−3	6	−3			3		2	−6
(32^2)	$\frac{1}{2}$												−2	1	−1	2
(321^2)	$\frac{1}{2}$						1	−1	4	−2		−2	3	−1	4	−6
(2^31)	$\frac{1}{6}$								2	−3	1		6	−3	3	−6
(31^4)	$\frac{1}{24}$			1	−4		−6	12	−24	12		8	−12	3	−14	24
(2^21^3)	$\frac{1}{12}$				−1	1	−6	6	−18	15	−3	6	−18	8	−14	24
(21^5)	$\frac{1}{120}$		1	−5	20	−10	50	−60	120	−90	15	−40	84	−35	70	−120
(1^7)	$\frac{1}{7!}$	1	−21	70	−210	105	−420	504	−840	630	−105	280	−504	210	−420	720

TABLE OF

Indices of S_r's ⟶	1^8	1^62	1^53	1^44	1^42^2	1^323	1^35	1^26	1^224	$1^2 2^3$
Symmetric Functions / Common Factors										
(8)										
(71)										
(62)										
(61^2)	$\frac{1}{2}$							1		
(53)										
(521)										
(51^3)	$\frac{1}{6}$						1	−3		
(4^2)	$\frac{1}{2}$									
(431)										
(42^2)	$\frac{1}{2}$									
(421^2)	$\frac{1}{2}$							−1	1	
(3^22)	$\frac{1}{2}$									
(3^21^2)	$\frac{1}{4}$							−1		
(32^21)	$\frac{1}{2}$									
(2^4)	$\frac{1}{24}$									
(41^4)	$\frac{1}{24}$				1		−4	12	−6	
(321^3)	$\frac{1}{6}$					1	−1	6	−3	
(2^31^2)	$\frac{1}{12}$							2	−3	1
(31^5)	$\frac{1}{120}$			1	−5		−10	20	−60	30
(2^21^4)	$\frac{1}{48}$				−1	1	−8	8	−36	30	−6
(21^6)	$\frac{1}{6!}$		1	−6	30	−15	100	−120	360	−270	45
*(1^8)	$\frac{1}{8!}$	1	−28	112	−420	210	−1120	1344	−3360	2520	−420

* The expansions of (1^7), (1^8) and (1^9) can be written down at once from the tables of group characters of degrees 7, 8 and 9 thus:—Consider the class as the indices of S_r's; so that $1^2\,24 \equiv S_1^2\,S_2\,S_4$ etc., the co-efficients of the class are the product of the elements in $[1^7]$ etc., and the corresponding orders. Multiplying by $\frac{1}{7!}$, $\frac{1}{8!}$, $\frac{1}{9!}$, respectively, the expansions of (1^7), (1^8), (1^9) are easily obtained.

DEGREE 8

$1^2 3^2$	125	$12^2 3$	134	17	8	4^2	$2^2 4$	26	23^2	35	2^4
					1						
				1	−1						
					−1			1			
				−2	2			−1			
					−1					1	
	1			−1	2			−1		−1	
	−3			6	−6			3		2	
					−1	1					
			1	−1	2	−1				−1	
					2	−1	1	−2			
	−2		−2	4	−6	2	−1	3		2	
					2			−1	1	−2	
1			−4	4	−6	2		1	−1	4	
	−2	1	−1	2	−6	1	−1	4	−2	4	
					−6	3	−6	8			1
	12		8	−24	24	−6	3	−12		−8	
−3	9	−3	12	−18	24	−6	3	−12	5	−14	
	12	−6	6	−12	24	−6	9	−20	6	−12	−1
20	−60	15	−70	120	−120	30	−15	60	−20	64	
12	−72	32	−56	96	−120	30	−33	84	−28	64	3
−120	504	−210	420	−720	720	−180	180	−480	160	−384	−15
1120	−4032	1680	−3360	5760	−5040	1260	−1260	3360	−1120	2688	105

TABLE OF

Symmetric functions	Common factors	1^9	1^72	1^63	1^54	1^52^2	1^32^3	1^45	1^36	1^324	1^23^3	1^33^2	1^25	1^22^23	1^234	1^27
(9)																
(81)																
(72)																
(71^2)	$\frac{1}{2}$															1
(63)																
(621)																
(61^3)	$\frac{1}{6}$								1							−3
(54)																
(531)																
(52^2)	$\frac{1}{2}$															
(521^2)	$\frac{1}{2}$												1			−1
(4^21)	$\frac{1}{2}$															
(432)																
(431^2)	$\frac{1}{2}$														1	−1
(51^4)	$\frac{1}{24}$							1	−4				−6			12
(3^3)	$\frac{1}{6}$															
(42^21)	$\frac{1}{2}$															
(3^221)	$\frac{1}{2}$															
(32^3)	$\frac{1}{6}$															
(421^3)	$\frac{1}{6}$								−1	1			−3		−3	6
(3^21^3)	$\frac{1}{12}$								−1			1			−6	6
(32^21^2)	$\frac{1}{4}$												−2	1	−1	2
(2^41)	$\frac{1}{24}$															
(41^5)	$\frac{1}{24}$							1	−4				−6			12
(321^5)	$\frac{1}{24}$						1	−1	8	−4	0	−4	18	−6	24	−36
(2^31^3)	$\frac{1}{36}$								2	−3	1	0	18	−9	9	−18
(31^6)	$\frac{1}{61}$			1	−6	0	−15	30	−120	60	0	40	−180	45	−210	+360
(2^21^5)	$\frac{1}{240}$				−1	1	−10	10	−60	50	−10	20	−180	80	−140	240
(21^7)	$\frac{1}{71}$		1	−7	42	−21	175	−210	840	−630	105	−280	1764	−735	1470	−2520
(1^9)	$\frac{1}{91}$	1	−36	168	−756	378	−2520	3024	−10080	7560	−1260	3360	−18144	7560	−15120	25920

DEGREE 9

18	14^2	12^24	126	123^2	135	12^4	45	3^3	36	234	27	225	2^33	9
														1
1														−1
											1			−1
−2											−1			2
									1					−1
−1			1						−1		−1			2
6			−3						2		3			−6
							1							−1
−1					1		−1		−1					2
							−1				−2	1		2
4			−2		−2		2				3	−1		−4
−1	1						−2							2
							−1		−1	1	−1			2
4	−2				−2		4	0	+2	−1	1			−6
−24			12		8		−6		−8		−12	3		24
								1	−3					2
2	−1	1	−2				3		2	−2	4	−1		−6
4			−1	1	−2		2	−1	5	−2	2			−8
							3		2	−3	6	−3	1	−6
−18	6	−3	9		6		−12		−8	5	−12	3		24
−18	6		3	−3	12		−12	2	−14	6	−6			24
−12	2	−2	8	−4	8		−10	2	−14	9	−14	4	−1	24
−6	3	−6	8			1	−12	0	−8	12	−24	12	−4	24
−24			12		8		−6		−8		−12	3		24
96	−24	12	−48	20	−56	0	54	−8	64	−38	60	−15	3	−120
72	−18	27	−60	18	−36	−3	54	−6	58	−51	90	−36	11	−120
−720	180	−90	360	−120	384	0	−324	40	−360	210	−360	90	−15	720
−600	150	−165	420	−140	320	15	−324	40	−360	280	480	174	−50	720
5040	−1260	1260	−3360	1120	−2688	−105	2268	−280	2520	−1890	3240	−1134	315	−5040
−45360	11340	−11340	30240	−10080	24192	945	−18144	2240	−20160	15120	−25920	9072	−2520	40320

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THE IMPORTANCE OF THE PRIMARY ABSORPTION PROCESS IN PHOTO-CHEMICAL REACTIONS. PART I.

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SUMMARY

The effect of the primary absorption process on the net photo-chemical change has been studied and it has been emphasised that this method of studying photo-chemical reactions in solutions in stages is entirely a new one and it will help a good deal in clearing off some of the contesting problems regarding Temperature co-efficient and Quantum yield in photo-chemical reactions.

With the development of the modern method of researches in photo-chemical reactions the rôle of the primary absorption process in gaseous reactions has been of great importance in discussing the mechanism of the total (primary and secondary) photo-chemical change.

The phenomenon of light absorption by both the atomic and molecular systems has been studied by Franck,[1] Rollefson[2] and others and it has been argued that in atomic system such as mercury vapour the absorption of $\lambda=2537\text{Å}$ excites the normal mercury atom to a higher energy level and this is represented thus :—

$$Hg + h\nu \rightleftharpoons Hg'$$

The reverse arrows indicate that Hg' may loose its excitation energy and revert back to the normal state, but if any other gas molecule is present along with mercury vapour then the energy rich mercury atom will react with it as $Hg' + H_2 = HgH + H$. Similarly, for atomically bound molecules if the absorption lie in the continuous region then according to Franck[3] the molecules will be dissociated into atoms and one of the atoms will pass to the excited state as represented below :—

$$I_2 + h\nu = I + I' \ (\lambda = 4995\text{A}^\circ)$$

and in presence of any other reacting component along with Iodine vapour, the excited Iodine vapour thus formed will react and give us the net photo-chemical change. With ionically bound molecules such as NaCl, NaI, etc., the primary absorption process produces a variety of products. With NaI three maxima of absorption

are obtained and the energy equivalent to these maxima support the following equations:

$$NaI + E = Na + I$$
$$NaI + E_1 = Na + I'$$
$$NaI + E_2 = Na' + I$$
$$NaI + E_3 = Na'' + I$$

Here again we find the dissociation of the molecule either to two normal atoms or a normal atom and an excited atom. These atoms are then responsible for bringing about the net photo-chemical change. In addition to these, the primary absorption process with gaseous molecules shows evidence of the existence of energy rich molecule which subsequently either gives out its energy as fluorescent radiations or undergoes dissociation by collision with other molecule.

This, in brief, is the exact position of the present idea about the primary absorption process in photo-chemical reactions. Although much importance has been attached to the primary absorption process yet almost no attempt has been made to experimentally study the sole effect of its influence on the net photo-chemical reaction. Mellor[4] has pointed out that the period of induction in Hydrogen and Chlorine reaction disappears when exposed Chlorine is added to Hydrogen, but this he has studied in connection with the after-effect phenomenon. Ghosh and Banerji[5] have shown that the induction periods observed in reactions brought about by circularly polarised light disappear when the photo-active sols (WO_3 etc.) have been exposed to radiation for a sufficient time before mixing with the other components.

The nature of the primary absorption process in photo-chemical reaction involving solutions is not yet known. A few examples of the phenomenon of the after-effect[6] are, however, on record and their results indicate that the life period of excited molecules or atoms in solutions is much greater than in gaseous conditions. This fact has led me to study the influences of the primary absorption process in photo-chemieal reactions involving solutions.

I have studied the rate of reaction between Potassium Oxalate and Iodine, Tartaric acid and Bromine, and Ammonium Oxalate and Mercuric Chloride in dark and also with exposed light absorbing components, and in each case I have found an appreciable increase in the velocity of the reactions in the initial stages with exposed samples. With reactions involving halogens there is a difference of 0·3 to 0·4 cc. in the titre values with hypo when exposed halogens were added to the other components, with Ammonium Oxalate and Mercuric Chloride the precipitation of Calomel has been observed when exposed Ammonium Oxalate was added to Mercuric Chloride. With unexposed samples there was no reaction at all. I made sure that there was absolutely no Iron salt present with Ammonium Oxalate to bring about the Photo-decomposition of the exposed Oxalate solution.

These experimental observations together with the recorded results of the existence of an after-glow in illuminated mercury vapour and the appearance of a yellow colour from a colourless solution of Iodoform in Chloroform when an exposed sample of Iodoform is added to it has enabled me to emphasise that in photo-chemical reactions in solutions, we can study the exact rôle of the primary absorption process in the net photo-chemical change and this method of studying photo-chemical reactions in stages shall open a new line of research so far the mechanism, temperature coefficient and quantum efficiency of photo-chemical changes are concerned.

Further work on this line is in progress in this laboratory.

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CHEMICAL EXAMINATION OF THE ESSENTIAL OIL OF CURCUMA CAESIA ROXB.

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SUMMARY

1. The rhizomes of *Curcuma caesia* Roxb., on steam distillation, yielded 1·6 per cent of a pale yellow essential oil which on standing for some time partially solidified with deposition of camphor.

2. On further examination it was found that at least 56 per cent of d-camphor could be recovered from the essential oil. A considerable quantity of camphor remained in solution in the mother liquors.

3. The essential oil of *Curcuma caesia* would indeed form an excellent source of camphor of purely Indian origin, if extracted on a large scale. The average yield of camphor from *Cinnamonum camphora* of Chinese or Japanese origin is never more than 1·5 per cent on the weight of the wood, while the rhizomes of *Curcuma caesia* yield about 0·9 per cent of camphor calculated on the weight of the dry material. Unlike the camphor laurel which requires careful cultivation for years, *Curcuma caesia* grows wild and is a much cheaper raw material in consequence.

Curcuma cæsia (Scitamineæ) is an oft cultivated plant in Bengal. The rhizomes or tubers of this plant are known as "Kala Haldi" in Bengali and "Kapur Kachri," "Kachri" or "Narkachur" in Hindi. They are a commercial commodity and are largely employed for blending with smoking and chewing tobacco in order to impart a fine aroma to them. They are also used in scenting hair oils and as incense in powder form.

The drug is highly medicinal. The fresh root is considered as cooling and diuretic. It checks leucorrhœa and gonorrhœal discharges and purifies the blood. The rhizomes possess aromatic, stimulant and carminative properties and are employed as stomachic and also applied to bruises and sprains as antispetic and rubefacient. The root is chewed to correct a sticky taste in the mouth. It is also an ingredient in some of the strengthening conserves which are taken by women to remove weakness after child-birth. In colds it is given in decoctions with long pepper, cinnamon and honey, and the pounded root is applied as a paste to the body. The Turks employ these roots as rubefacient to rub their bodies with, after taking a Turkish bath. In Bengal it is used in fresh state like turmeric.

The root was analysed by Dymock[1], and the following composition was given:—

Essential oil and resin	4·47 %
Resins, sugars etc.	1·21 „
Gums, organic acids etc.	10·10 „
Starch	18·75 „
Crude fibre	25·20 „
Ash	7·57 „
Moisture	9·76 „
Albuminoids	22·94 „
	100·00 „

In view of the fact that the essential oil which appears to constitute the most important ingredient of the rhizome, has not yet been chemically examined, it was thought very desirable to undertake the investigation. It is rather surprising that although the tubers are cheap and contain a comparatively large proportion of essential oil, no attempts seem to have been made in India to make it a commercial proposition. In view of the large yield of camphor (56 per cent) obtained from the oil, it would indeed form an excellent source of camphor of purely Indian origin, when worked up on a large scale.

Experimental

Six kilos of the authentic specimen of the root were obtained from the local market, pulverized and distilled from a copper still fitted with a condensing still head. 95·5 gr. of a light brown essential oil were recovered from the distillate (30 litres) by extraction with petroleum ether and subsequent removal of the solvent. After filtration and drying with anhydrous sodium sulphate, the oil was examined and found to have the following constants:—

Table I

Constants of the essential oil

Sp. Gr. (15°C)	0·8450
Refractive index (15°C)	1·5050
Optical rotation (32°C)	+32°
Saponification value	nil
Acid value	nil

Rectification of the essential oil. – The oil was then submitted to distillation under reduced pressure (5 mm.) and the various fractions collected are given in the following table :—

TABLE II

Fractions of the essential oil

Fraction No.	Boiling range (°C.)	Weight of fraction (gms.)	Weight of crystalline matter from the fraction
1	up to 45	4·6	nil
2	45—80	5·1	nil
3	80—100	6·9	nil
4	100—120	4·1	nil
5	120—130	2·3	nil
6	130—140	7·4	8·4
7	140—160	3·8	
8	160—180	8·4	0·6
9	180—200	9·2	16·1
10	200—210	11·83	
11	210—220	11·52	4·8
12	Residue	9·4	...

The solid crystalline matter separating out from the various fractions was filtered off and crystallized from alcohol. On examination, each one of them was found to consist of pure d-camphor, melting at 176°C. The oxime and the semicarbazone prepared in the usual manner melted at 118°C and 237°C respectively.

The physical properties of the various fractions were determined and are given in the following table :—

TABLE III

Physical constants of the fractions

Fraction No.	Sp. Gr. (15°C)	Refractive index (15°C)	Optical rotation (32°C)
1	0·821	1·4050	+47·25
2	0·845	1·4040	+74·25
3	0·804	1·4320	+72·12
4	0·871	1·4550	+86·75
5	0·896	1·5050	+86·75
6	0·964	1·4650	+.....
7	0·971	1·4850	+136·75
8	0·992	1·5000	+111·75
9	1·003	1·5040	+115·46
10	1·014	1·5120	+118·36
11	1·011	1·5100	+122·45

Fraction Nos. 1, 2, 3, and 4 were mixed together and redistilled at the ordinary pressure, when the following fractions were collected :—

TABLE IV

Redistillation of the lower fractions.

Fraction No.	Boiling range (°C)	Weight of fraction (gm.)	Weight of camphor obtained
13	80—100	2·7	...
14	100—120	1·1	...
15	120—140	4·2	12·2
16	140—180	10·4	
17	Residue	1·3	

The mother liquors from the various fractions after filtration and removal of camphor could not be definitely identified as they still contained some camphor in solution. But from qualitative reactions they appeared to me unsaturated terpene hydrocarbons of the bicyclic and sesquiterpene series. The quantities left after separation of camphor were insufficient for any detailed chemical examination.

One of the authors (B. K. M.) wishes to express his indebtedness to the Kanta Prasad Research Trust of the Allahabad University for a Scholarship which enabled him to take part in the present investigation.

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CONSTITUTION OF CUSCUTALIN

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SUMMARY

The colourless, crystalline substance "cuscutalin", obtained previously by Agarwal and Dutt from *Cuscuta reflexa*, has, on further examination by the present authors, been found to be a wax mixed with a large amount of solid hydrocarbons of the paraffin series. The wax has been found to consist of esters of higher aliphatic alcohols with saturated aliphatic mono-carboxylic acids containing 26 and 28 carbon atoms, amongst which cerotic acid has been definitely identified.

Agarwal and Dutt (2), in the course of their investigation on the chemical constituents of *Cuscuta reflexa*, Roxb (Convulvulaceæ), isolated from it a white crystalline substance of the nature of a lactone called by them cuscutalin. It is recorded to melt sharp at 68°, and as a result of elementary analysis and molecular weight determination in phenol, the formula $C_{18}H_{10}O_4$ was assigned to it. It was found to be optically active $(\alpha)\frac{27^\circ}{D} = 8^\circ$ (in chloroform). In chemical structure it was found to be a hydroxy $\beta\gamma$-unsaturated lactone on account of its colour reactions with alcoholic potassium hydroxide, slow neutralisation with caustic potash and colour reaction with alkaline sodium nitroprusside. The phenolic character was confirmed by reaction with ferric chloride and also by the preparation of acetyl-benzoyl-methoxy-and carbethoxy-derivative and the presence of an unsaturated linkage was shown by quantitative estimation with bromine. By fusion with caustic potash the substance was found convertible into cinnamic acid and a hydrocarbon melting at 80-84°C, which was not further investigated.

The present authors' attention was drawn towards the problem of the constitution of cascutalin from the last phase of the above-mentioned work by Agarwal and Dutt, *i.e.*, the potash fusion of cuscutalin in which a hydrocarbon was isolated from the melt. It is very difficult to imagine that a hydrocarbon could be formed as the result of caustic potash fusion of an unsaturated phenolic lactone unless it was originally present in the compound. The only example of the isolation of a hydrocarbon from the products of potash fusion is that from the aglucone $C_{17}H_{14}O_6$ of a colouring matter m.p. 240° isolated from the flowers of *Linarea vulgaris*, has been shown by Schmidt and Rumpel (5) to be due to the presence of a hydrocarbon hentriacontane in the original substance. Consequently, the present investigation was undertaken with a view to elucidate correctly the constitution of cuscutalin.

A better method of isolation of cuscutalin has been worked out; cuscutalin has now been isolated in a very pure state; in this condition, however, it is not found to respond to many of the colour reactions mentioned by previous authors. Further work on its structure indicates that it is of the nature of wax admixed with a large amount of solid crystalline hydrocarbons of the paraffin series. The wax has been saponified and the mixed acids together with the unsaponifiable matter isolated. The mixed acids are saturated and belong to the stearic acid series; and on fractional crystallization they have been found to be the higher fatty acids of carbon atoms 26, 28, and 30, usually found in plant waxes. The unsaponifiable matter has been found to consist mainly of crystalline hydrocarbons of the paraffin series mixed with a small quantity of higher alcohols It is of interest to note that it is really the wax as the outer coating on the *Cuscuta reflexa* that protects the parasitic creeper from the strong tropical sun and allows it to retain a large percentage of moisture, the coating of wax reducing the loss of moisture to a minimum.

Experimental

Several kilograms of fresh *Cuscuta reflexa* were collected in the neighbourhood of Allahabad in the months of August, September, October, and November, from various host plants; when dried in the sun, they lost 90-93% of water. In a perfectly dried state, the plant was easily powderable. The powdered material was extracted in instalments of 2 Kgs. with boiling alcohol in a big extraction flash of 5 litre capacity, according to the method of Agarwal and Dutt (2) till the extract failed to give any white deposit on cooling. The various extracts, which were of a light yellow colour were filtered hot and, on cooling, deposited a greyish white crystalline substance, which was filtered off, washed with a little cold alcohol and dried. The cuscutalin thus obtained was a sticky crystalline magma and responded to many of the tests and colour reactions recorded by Agarwal and Dutt. (Yield 23·0 g.).

Isolation of Pure Cuscutalin—The crude material thus obtained was twice recrystallized from large quantities of boiling alcohol when a little dark brown material—consisting of the powdered creeper, mineral and other foreign material—was left undissolved even on repeated refluxing with large quantities of ethyl alcohol. Thus, it was obtained as white flakes of waxy touch, and the sample, dried in vacuum desiccator, melted at 67-68°C. after softening at 64°C. It was finally crystallized from boiling methyl alcohol in which it is much less soluble; the whole process is rather tedious (yield 16·5 g.). The significant point observed was that, on repeated refluxing with large quantities of methyl alcohol, all crystalline matter was dissolved and that only a trace of the dark brown stuff was left undissolved. It was also observed that the first two hot extracts deposited a white crystalline substance in the form of flakes having a slightly different melting point than that of the crystals from the last two extracts, thus indicating significantly that a mixture of allied substances was

being handled. The separation of the various constituents by this method, besides being tedious, did not give hopes of complete and satisfactory results, and consequently, was not followed. The substance was naturally pure and free from fatty matter originally present. It was later on found that it was not necessary to follow the tedious process of crystallization from boiling methyl alcohol and three or four crystallizations from ethyl alcohol gave an equally pure sample.

The alcoholic mother-liquors left after crystallization of the so-called "Cuscutalin" was concentrated when a little more of the substance was recovered and, on recrystallization, obtained pure. The final mother-liquor did not contain any lactone except tannins and reducing sugars.

A much better and convenient method of isolating the so-called "cuscutalin" of Agarwal and Dutt is as follows: The powdered material (2·5 Kg.) is extracted repeatedly with hot benzene in a 5-litre extraction flask till a portion of the extract on complete evaporation, does not leave any residue. The extract which was of a light yellow colour was filtered hot, the solvent recovered as completely as possible by distillation, the syrupy hot mass transferred to a 2-litre, round-bottomed flask, and the last traces af benzene removed by heating in a water bath and finally in vacuum. The dirty yellow crystalline magma was thrice crystallized from boiling ethyl alcohol when it was obtained as white crystalline flakes (m.p. 67-68° after shrinking at 64°).

Properties—The so-called "cuscutalin", thus obtained melted at 67-68° after previous shrinking at 64° and the melting point remained unchanged by subsequent recrystallizations. The substance, though having nearly the same melting point as recorded by Agarwal and Dutt, differed greatly in physical and chemical properties as recorded by the previous authors. It is obtained as white flakes waxy to the touch, and is only fairly soluble in cold benzene, chloroform, pyridine, ether and petroleum ether and very readily in the hot; it is almost insoluble in cold ethyl alcohol, methyl alcohol, ethyl acetate, and acetone, but fairly soluble in the hot. It does not give a positive Salkowski's (4) reaction. Thus, to a solution of the substance in chloroform a little concentrated sulphuric acid was added when no coloration appeared even on standing. In Liebermann's reaction and in Liebermann-Burchard (3) Reaction a pinkish-violet coloration appears on standing, showing that the wax contains some alcohol having a large number of carbon atoms and probably related to sterols. With concentrated sulphuric, hydrochloric and nitric acids it does not give any coloration even on heating (cf. Agarwal and Dutt). It gives no precipitate with lead acetate and silver nitrate, nor any coloration with alcoholic ferric chloride. It is insoluble in boiling concentrated aqueous or alcoholic caustic potash and no yellow coloration appears (cf. Agarwal and Dutt). It neither reduces Tollen's reagent, nor gives any coloration with it under any circumstances. Further, with alkaline solutions of potassium nitroprusside it gives no coloration.

Thus, it is evident that this white substance is really the so-called "cuscutalin" of Agarwal and Dutt, but in a purer form and free from the tannin matter abounding in *Cuscuta reflexa* and the yellow flavone isolated from the seeds of *Cuscuta reflexa* (cf. Agarwal 1). (Found, Sample dried in vaccum, C, 84·25, 84·05; H, 14·12, 14·25; cf. $C_{18}H_{10}O_4$ (Agarwal and Dutt) requires C, 74·5; H, 3·4; M, 290).

Neutralization Value of "Cuscutalin" or Wax.—(1·0092 g. (1·2980 g; 1·3940 g.) of cuscutalin were refluxed with distilled alcohol (200 c.c.) for an hour and the cooled mixture was titrated with standard aqueous caustic potash (N/20·8) in presence of phenolphthalein to neutralization point with continuous shaking; the mixture was then refluxed in order to dissolve any free fatty acid which had separated out and subsequently re-titrated after cooling to neutralization point; again refluxed and cooled when it was found not to require any more alkali. In a blank experiment 200 c.c. of alcohol were refluxed similarly for an hour and titrated with caustic potash. Acid value was thus found to be 8·25; 8·50; 8·44 (cf. Agarwal and Dutt, 17·8).

Saponification Value.—The neutral solution left after the determination of acid value was refluxed with 25 (or 30 c.c.) of N-alcoholic caustic potash solution for 3 hours on the water bath. The mixture was cooled and the excess of alkali titrated with standard aqueous caustic potash (N/15·44); while in a blank experiment a mixture of 15·44 alcohol (200 c.c.), 25 (or 30) c.c. of N-alcoholic caustic potash and water (10 c.c.) was refluxed on the water bath for the same period. Thus, the saponification value was found to be 24·8, 25·1 while with still dilute alcoholic caustic potash (N/2·83) and 20 or 40 c.c. of alcohol saponification value was found to be as low as 16·6, 17·4 evidently owing to incomplete saponification. The use of 25 or 30 c.c. of alcoholic caustic potash (about 3 N) did not lead to any rise in the saponification value (25·3) (cf. Agarwal and Dutt found 173·9).

Saponification of Wax.—An alcoholic solution of potassium hydroxide (25 c.c. of 4·5%) was added to the wax (8·4 g.) dissolved in warm benzene (44 c.c.) and the mixture refluxed for 3 hours on the water bath. Water (44 c.c.) was then added and the mixture again heated for 10 minutes. The warm benzene layer was separated after addition of some more benzene and the aqueous solution repeatedly extracted with benzene till 50 c.c. of it left no residue on complete evaporation. The benzene solutions were combined and washed with water till neutral towards litmus. On removal of benzene by distillation, the unsaponifiable matter was obtained as glistening white flakes.

Fatty Acids.—The saponification mixture left after complete extraction with benzene was acidified with excess of dilute sulphuric acid and the precipitated acid removed by extraction with benzene. The almost white fatty acids (1·4 g.) thus obtained had the m.p. 78-81°, molecular weight by titration was 414, 418 clearly showing that it was the usual mixture of higher fatty acids of paraffin series having

carbon atoms 26, 28, and 30 usually found in plant waxes. The fatty acids were fractionally crystallized from hot ethyl alcohol and thus four fractions in order of increasing solubility were obtained. These fatty acids were partly present as wax esters in combination with long chain alcohols and partly as free acids; the percentage of alcohol in the unsaponifiable matter is evidently small since the ester value (Saponification Value minus Acid Value) is small, 6.7.

Fraction I.—Light brownish in colour, m.p. 85° after shrinking at 84°. (Found C, 79·1, H, 13·14; $C_{28}H_{56}O_2$ requires C, 79·3; H, 13·3; H. 424). It is saturated

Fraction II.- Almost white in colour, glistening needles m.p. 84-85° after shrinking at 82° (Found C, 78·92; 78.70; H, 13·12; 13·13; $C_{26}H_{52}O_2$ requires C, 78·7; H, 13·2, M, 396; $C_{28}H_{56}O_2$ requires C, 79·3; H, 13·3; M, 424).

Lewkowitsh gives the m.p. of pure cerotic acid $C_{26}H_{52}O_2$ as 77·8° (corr). This fraction consists of cerotic acid and $C_{28}H_{56}O_2$ acid.

Fraction III.—Absolute white, glistening needles, m.p. 76-77°C after shrinking at 74°C (Found C, 78.43; H. 13·08; while $C_{26}H_{52}O_2$ requires C,78 7, H, 13·2.

Fraction IV.—Absolute white glistening needles m.p. 75° after shrinking at 74°.

Unsaponifiable Matter obtained above was fractionally crystallized from light petroleum ether and thus the four fractions described below were obtained:

1. *Fraction*—white flakes m p. 70-71·5° after losing its crystalline structure at 68°.
2. *Fraction*—white flakes m.p. 65-66° after losing its crystalline structure at 58°. (Found C, 84·26, 84·32; H, 14·56, 14·55)
3. *Fraction*—white flakes m.p. 63·5-65° after losing its crystalline structure at 57·5-58°.
4. *Fraction*—white flakes m.p. 62-63° after losing its crystalline structure at 60 C.

The above results show that the unsaponifiable matter consists primarily of normal paraffins mixed with some alcohols. It is proposed to proceed further with the separation of the paraffins, primary or secondary alcohols and ketones occurring in the unsaponifiable matter when sufficient quantity of this is available.

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CONSTITUENTS OF *PTEROCARPUS DALBERGIOIDES*, ROXB

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SUMMARY

Detailed chemical examination of the wood of ***Pterocarpus dalbergioides***, Roxb, known as Andaman Padauk in English, has revealed the presence of santalin $C_{34}H_{28}O_{10}$ as the colouring matter of wood along with the colourless phenolic compounds, santal. $C_{13}H_{10}O_3$ m. p. 216°, and two neutral and inert colourless compounds pterocarpin $C_{17}H_{14}O_5$ m. p. 165° and homopterocarpin m, p. 87-88°, which had previously been isolated from ***Pterocarpus santalinus*** Linn. (Red Sanders Wood) Pure crystalline santalin was obtained via its crystalline hydrochloride $C_{34}H_{29}O_{10}Cl$.

Pterocarpus dalbergioides, Roxb., known in English as "Andaman Padauk" belongs to the sub-division papilionatae of the Natural Order Leguminosae, and grows profusely in the Andaman Islands. It is a tall or medium sized deciduous tree growing to a height of 80—125 feet. The tree has leaves alternate, stipulate and compound, and the flowers are in large, much-branched, terminal panicles. The fruit is a pod and, as a rule, one-seeded. The trunk of the tree is frequently much buttressed and yields a valuable ornamental wood, the colour of which varies in shade from brown through reddish brown, dull red, cherry-red to deep crimson. The most commercially valuable wood is the crimson one. The seasoned wood weighs 48 lbs. per cubic foot, but it seasons with difficulty. It works well, does not warp or crack and takes a fine polish. This beautiful timber has been used for a variety of purposes especially for furniture-making and ornamental work. But on account of the difficulty in seasoning the wood, it is not being as extensively used in furniture-making as it should be.

As no work has been done on its colouring matter, which is easily removed by extraction with alcohol or ethyl acetate, the present investigation was undertaken with a view to isolating the colouring matter in a pure state and elucidating its constitution.

On examination it was found that the wood contains 75·8—75·2% of cellulose and 19·46% of ash having the following elements and radicals: sodium, potassium, magnesium (traces), calcium, phosphate, carbonate, silica and nitrate.

But, from the Chemical point of view, the most important constituent present in the wood is the colouring matter, which on investigation was found to be identical with santalin $C_{34}H_{28}O_{10}$, which is also the colouring matter of many other interesting woods like *Red Sanders Wood* (*Pterocarpus Santalinus Linn*), *Cam wood* derived from a variety of *Baphia nitida*, *Narra wood* (*Pterocarpus Sappan*), and

Barwood (*Baphia nitida Lodd*). Along with the colouring matter there is present the phenolic compound *santal* $C_{13}H_{10}O_3$ m.p. 216° and the two neutral and inert compounds *pterocarpin* $C_{17}H_{14}O_5$ m. p. 165° and *homopterocarpin* $C_{17}H_{16}O_4$ m. p. 87—88° which had been previously isolated from *Red Sanders Wood*. (3,4,7,8,9).

Experimental

For exhaustive extraction with different solvents the fine dust (20·0 g.) was taken in a soxhlet's extractor and successively extracted with benzene, ethyl acetate and ethyl alcohol; the solvent was evaporated in each case and the residue brought to a constant weight by heating in a steam oven, with the following results :—

1. *Benzene Extract* (3·47%). A light brownish-pink oily mass consisting of fatty and oily matter.

2. *Ethyl Acetate Extract* (14·95%). Brownish-red sticky mass giving, with alcoholic ferric chlorides, a reddish-violet coloration, with caustic alkali a bluish-violet coloration, which rapidly turns brown and reducing ammoniacal silver nitrate and Fehling's solution.

3. *Alcohol Extract.* (2·56%). A brown-red brittle mass, giving reactions very similar to that of ethyl acetate extract. On extracting separately with different solvents the following results were obtained: (1) Alcoholic Extract, 13·21%; (2) Acetone Extract, 12·12% ; (3) Ethyl acetate, 11·21%.

The saw dust of the wood when completely incinerated left 19·46% of flesh-coloured ash containing 10·98% of water-soluble and 89·12% of water-insoluble ash. In the ash the following elements and radicals were detected: sodium, potassium, calcium, magnesium, iron, silica, aluminia, carbonate, phosphate, chloride, sulphate and nitrate (in traces).

For determination of cellulose (6) including cellulosan, the dust of wood, which had been extracted with benzene-alcohol mixture, was air dried and then treated twice with neutral sodium hypochlorite solution (3·8%) and three times with acid sodium hypochlorite solution; each sodium hypochlorite treatment being followed by boiling with sodium sulphite solution (3·8%).

3·2 Kgs. of the fine shavings of wood, in lots of 0·8 Kgs. were exhaustively extracted with rectified spirit in a 5-litre extraction flask. The combined yellowish-red extracts were concentrated when a syrupy residue was obtained, and on long standing (10 days), deposited a small amount of soft crystalline substance. It was diluted and thoroughly stirred with ice-cold ethyl alcohol (200 c.c.) when it was obtained in an easily filtrable condition. It was filtered at the pump with good suction and the residue (A) was washed with a little ice-cold alcohol until it had assumed a brownish-pink colour and was reserved for subsequent examination. The filtrate was diluted with twice its volume of hot alcohol and treated with a hot

alcoholic solution of lead acetate until no further precipitate was formed. The mixture was then heated under reflux for 40 minutes and allowed to stand for some hours and then filtered hot at the pump. The violet lead lake was thus thrice refluxed with alcohol and subsequently filtered and washed at the pump so that the filtrate was only of light brownish pink colour. The lead lake was finally well washed with boiling water, suspended in alcohol and decomposed by passing a current of pure sulphuretted hydrogen, the resulting lead sulphide having been filtered off and well washed with hot alcohol. The orange red solution after removal of sulphuretted hydrogen by a current of carbon dioxide was concentrated and then allowed to stand for a few days when it deposited just a small amount of a white crystalline substance (B) which was filtered at the pump and washed with ice-cold alcohol and reserved for further examination.

The alcoholic filtrate and washings were combined and concentrated under reduced pressure; on standing for a few days, the mixture deposited no crystalline substance and was finally evaporated to dryness under reduced pressure. The vermillion coloured residue (72 g., *i.e.*, 2·25%) was finely powdered and repeatedly extracted with hot ethyl acetate till the filtered solution was at most of pink colour and left no residue when an adequate portion of it was evaporated to dryness. The various ethyl acetate extracts (C) were combined and kept for further investigation. The insoluble colouring matter thus obtained has green irridescence and a deep cinnabar colour when powdered in a mortar. It softens at nearly 280°, and darkens in colour, decomposes and carbonizes at above 300° (yield 18·4 gms). It is insoluble in ether, benzene, petroleum ether, chloroform, carbon, tetrachloride and ethyl acetate, and soluble in alcohol, acetone and, very readily, in pyridine. Its orange red alcoholic solution gives a brownish violet coloration, with alcoholic ferric chloride a brownish-violet coloration with a trace of dilute caustic alkalies or sodium carbonate solution, and a violet precipitate with excess of caustic alkalies. Its orange red alcoholic solution, on addition of a few drops of Con. hydrochloric acid, at once turns intense cherry red showing the formation of oxonium salt. This colouring matter very much resembles santalin of O'Neill and Perkin (5) and of Dieterle and Stegmann (2) in physical and chemical properties. (Sample dried at 140° in air oven. C, 66·24, 66·38; H, 4·68, 4·71. $C_{24}H_{22}O_8$ (5) requires C, 66·1, H, 4·6, M.W., 438; $C_{30}H_{28}O_{10}$ (1) requires C, 65·7; H, 5·11; M. W., 540; $C_{31}H_{26}O_{10}$ requires C, 66·66; H, 4·66; M.W., 558).

Thus, it is evident that this colouring matter is identical with santalin, which the previous workers had isolated from *Pterocarpus Santalinus, Linn.*, and its further purification seemed necessary in view of the fact that H. Raudnitz, M. Navratil, and P. Benda (8) have obtained santalin in well defined crystals through its oxonium hydrochloride which was itself obtained in pure and well-defined crystals by precipitating with ether its 2 per cent methyl alcoholic

hydrochloric acid solutions – a device employed by Willstätter, Karrer, and their co-workers for isolation of anthocyanins.

Santalin: Ten gm. of Santalin obtained as described above was treated with 200 c.c. of 2 per cent methyl alcoholic hydrochloric acid when it readily dissolved completely, giving an intense cherry red solution, which, after standing for 24 hours in the ice-chest, deposited the colourless impurities in a crystalline state. On filtering the solution at the pump a small amount of light pink coloured substance (D) was obtained (1 gr.). The filtrate was transferred to a conical flask and dry ether added till distinct brownish-red turbidity appeared. After standing overnight in the ice-chest the hydrochloride of the dyestuff appeared as deep metallic green lustrous crystals. The crystalline mass was filtered off and redissolved in 200 c.c. of 2 per cent. methyl alcoholic hydrochloric acid and treated with ether till distinct turbidity appeared. On repeating the procedure several (five) times, the hydrochloride was obtained as magnificent green fluorescent needles with reddish-brown streak (yield 5·4 gr.) and responding to all the test and reactions of santalin chloride; for example, its cherry red alcoholic solution gave an intense violet coloration with alcoholic ferric chloride and a reddish violet coloration with dilute alkalies. In carrying out its analysis we met with the same difficulty as that observed in the case of anthocyanins and anthocyanidins by previous workers, namely, by drying in high vacuum at 100°, hydrogen chloride is split off and therefore the sample dried at room temperature in high vacuum over phosphorus penta-oxide till constant in weight, was used for elementary analysis. (Found C, 64·24; H, 4·83; Cl. 5·80; OCH_3, 20·14. $C_{34}H_{29}O_{10}Cl$ requires C, 64·48; H, 4·62; Cl. 5·60; OCH_3, 19·61).

The hydrochloride of the dye-stuff, on boiling with water, gave santalin in the form of cinnabar-red crystals with green irridescence, darkening in colour and decomposing without melting at above 316—318°. It is fairly easily soluble in alcohol and acetone to a deep orange red solution, readily, in pyridine, and insoluble in ether, petroleum ether, benzene, chloroform, carbon tetrachloride and ethyl acetate. (Found: Sample dried at 100° in high vacuum over phosphorus penta-oxide; C, 68·14; H, 4·88; OCH_3, 21·26; while $C_{34}H_{28}O_{10}$ requires C, 68·43; H, 4.73; OCH_3, 20·81).

Santal—From the combined ethyl acetate extracts (C) the solvent was removed by distillation and the residue dried in the vacuum desiccator melted at far below 100°. The dried residue was finely powdered and repeatedly extracted with boiling chloroform when its melting point gradually rose. After exhaustive extraction with boiling chloroform the residue melted at 215—216°, after shrinking at 200°, and was of brownish pink colour and soluble in hot alcohol, acetone, ethyl acetate, and slightly soluble in the cold but readily in hot pyridine. It was refluxed with sufficient quantity of ethyl acetate so

that the whole stuff dissolved completely, the resulting solution was filtered hot through filter paper. The resulting reddish-brown ethyl acetate solution, on standing in an ice-chest, deposited a considerable amount of a cystalline substance, which was filtered at the pump, washed with small quantities of ethyl acetate at a time, and finally with a little ice-cold methyl alcohol; a mixture comprising the colourless companions of santalin, but consisting mainly of santal was thus obtained in a crystalline form. The separation of pterocarpin and homopterocarpin from santal was effected by refluxing several times with sufficient quantity of carbon tetrachloride, whereby santal remained undissolved and the other two substances passed into solution. The insoluble residue, on repeated crystallization from alcohol with the aid of animal charcoal, became pure and finally crystallized in beautiful, faintly yellowish leaflets m.p. 216°. (Sample dried at 100° in high vacuum over P_2O_5. Found: C, 63·01; H, 4·48; $C_{18}H_{10}O_5$ requires C, 63·24; H, 4·30; OCH_3, 11·40).

Pterocarpin and Homopterocarpin —The combined carbon terachloride solution was evaporated to dryness and the residue treated with sufficient quantity of chloroform so that, on boiling the mixture, the whole of the stuff just dissolved. On cooling and allowing to stand overnight, pale yellowish crystals separated, which were filtered off and dried; they melted at 159—161° and, on repeated crystallization from alcohol with the aid of a little animal charcoal, were obtained as colourless clusters of needles, and the air dried sample melted at 165° (un-corr.)

(Found :—Sample dried at 25°C in high vacuum over phosphorus pentaoxide. C, 68·12; H, 4·80; OCH_3, 11·20. $C_{17}H_{14}O_5$, requires C, 68·43; H, 4·73; OCH_3, 10·41). It is very soluble in ether, petroleum ether, chloroform, and carbon tatrachloride, slightly in alcohol, ethyl acetate, and acetone, and insoluble in water. It was identified as pterocarpin.

The above carbon tetrachloride mother liquor deposited, on concentration, yet another crystalline substance, which after 12 crystallizations from alcohol, was obtained as long, colourless needles melting at 87—88° and found to be identical with homopterocarpin. (Sample dried at 25° in high vacuum over phosphorus pentaoxide. C, 71·60; H, 5·71; OCH_3, 22·28; $C_{17}H_{16}O_4$ requires C, 71·80; H, 5·67; OCH_3 21·84; M. 284). It is readily soluble in benzene, ether, petroleum ether, chloroform, carbon tetra-chloride, alcohol, ethyl acetate and acetone, and insoluble in water, dilute acids and alkalies; it gives no coloration with alcoholic ferric chloride, nor any precipitate with alcoholic lead acetate.

The sticky residue (A) which separated from the concentrated extract of the wood was extracted twice with 40 c.c. of boiling alcohol; the filtered solution gave, on concentration and cooling, pinkish crystals of the colourless companions of santalin, and the mother liquor, on concentration to a small volume, gave a little more of the same substance. It was subsequently resolved into homopterocarpin,

pterocarpin and santal. The residue, which remained undissolved in boiling alcohol gave, on extraction with chloroform, a small quantity of fatty oil.

The crystalline substance (B) was found to be a mixture of pterocarpin and homopterocarpin.

Further work on the constitution of santal and santalin is in progress.

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CHEMICAL EXAMINATION OF THE LEAVES OF *NEPETA RUDERALIS* HAMILT.—COMPOSITION OF THE ESSENTIAL OIL

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SUMMARY

The leaves of ***Nepeta Ruderalis*** Hamilt. yielded, on steam distillation, an essential oil, which was found to have the following constituents:

Fraction	Percentage
D-and *l*-limonene	20·8
Methyl heptenone	9·1
Citronellal	17·8
L-menthone	5·5
Citronellol	13

(*b. f.*)

Fraction	Percentage
Geraniol	7·6
Geranyl acetate	13·2
Residue unidentified sesquiterpenes	4·5

Nepeta Ruderalis Hamilt., known as Billilotan, is abundantly found in tropical and sub-tropical India: from Indus to Behar, Central India, the Konkan and on the slopes of the Himalayas up to 8000 ft. It is an annual herb, erect or ascending, pubescent or hoary. It is supposed to be a cardiac tonic and is largely used in fevers. The decoction is used as a gargle for sore throats. The Nepalis use it internally as a remedy against gonorrhoea.

It is of interest to note that this important drug of the Indian Materia Medica has not yet been chemically examined by any one. Another species: *Nepeta Japonica* Max (4) has been examined. The leaves were obtained from China and studied in Japan. By steam distillation of the leaves an essential oil (1·8 per cent) was obtained. The oil boiled at about 203°C or at 63-68°C at 10 mm. pressure. The constituents of this oil were thoroughly examined, but it was shown that it contained d-limonene and small quantities of free acids, esters and alcohols, though it consisted of a ketone $C_{10}H_{18}O$, which seemed to be d-menthone—the optical antipode of the common l-menthone.

This created interest in the leaves; on steam distillation, these yielded a pale yellow oil, which, on slight decomposition, turned brown. The oil was put to a thorough chemical examination as a result of which it has been definitely shown to consist of a mixture of d- and l-limonene, geraniol, citronellol, citronellal, methyl heptenone, geranyl acetate and l-menthone.

From its constituents the essential oil of the leaves of *Nepeta Ruderalis* Hamilt. appears to be somewhat similar to the essential oils obtained from the various lemon grasses of which geraniol and citronellol are the chief constituents. As a matter of fact, this essential oil is not very different from the oils of lemon grasses in physical properties. It can be easily used as a source of most of the chemicals required in synthetic perfumery.

Experimental

Ninety kilos of green leaves were collected from the neighbouring fields, and steam-distilled in a big copper distilling apparatus in lots of ten kilos each. The distillate was well shaken with petroleum ether (B. P. 40—60°C), and the solvent completely removed by distillation in an electric water-bath. This operation, however, is not enough; for petroleum ether is very tenacious and remains adhered to the oil even after the distillation on water-bath has come to an end. It is necessary, therefore, to carry on the distillation on an electric oil-bath; this operation requires much care in order that only the tenacious solvent may be evaporated leaving behind the volatile fraction of the oil, if any. For this purpose the distillation is done with the help of a Young's Columns fitted with a number of bulbs. After the solvent was thus completely removed, the essential oil was kept in a refrigerator to ascertain whether it deposited any solid substance or not. It was found that, even on prolonged cooling, no solid was deposited. The oil was, therefore, taken and its physical and some of its chemical constants determined. The result of this examination is given in Table I.

Table I

Specific Gravity	0·8684 at 22°C
Refractive index	1·4775 at 22°C
Acid value	8·5
Saponification value	40·8
Saponification value after acetylation ...	81·7
Optical Rotation	+16°5 at 20°C

The oil was then dried over Mg. So_4 and distilled under reduced pressure. Table II gives the results of this distillation.

TABLE II

Pressure : 68 mm. Total volume taken : 150 cc.

No.	Boiling range	Specific Gravity at 20°C	Optical Rotation at 20°C	Refractive index at 20°C	Volume (cc.)	Percentage
1.	Up to 100°C	0·8543	+40°	1·445	21·5	14·3
2.	100-150°C steady at 128°C	0·8596	+32°	1·462	10·6	7·1
3.	150-170°C steady at 165°C	0·8671	+10°	1·443	17·2	11·5
4.	170-190°C steady at 182°C	0·8741	+50°	1·498	34·5	23
5.	190-200°C steady at 195°C	0·8852	...	1·421	34·5	23
6.	200-220°C	0·8952	...	1·431	19·3	12·9
7.	above 220°C	0·8975	...	1·464	10·7	7·1
8.	Residue	...	...	...	...	...

The fractions 1, 2 and 3 were combined and distilled at ordinary pressure with the help of a Young's Fractionating Column having five bulbs. The physical constants of the various fractions so obtained were determined. These are given in Table III.

TABLE III

(Volume taken : 49·3 cc.)

Fraction	Boiling range	Specific Gravity at 20°C	Optical Rotation at 20°C	Refractive index at 20°C	Volume (cc.)	Percentage
1.	165-168°C	0·8519	+90	1·468	7·4	15
2.	168-169°C	0·8520	+100	1·468	8·7	17·8
3	169-170°C	0·8523	+8	1·468	8·3	16·9
4.	170-172°C	0·8521	−20·4	1·469	6·8	14·3
5.	172-174°C	0·8528	..	1·441	9·7	19·7
6.	174-176°C	0·8529	...	1·441	3·9	8
7.	Residue	0·8678	...	1·450	3·5	7·2

D-and l-limonene—The physical constants of the fractions 1-4 indicated the presence of a mixture of d-and l-limonene. The presence was confirmed by combining these fractions and treating a few cc. of the combined mixture with HCl in acetic acid solution. As a result of this, dipentene hydrochloride was obtained, which melted sharp at 50°C. This conclusively established the presence of a mixture of d-and l-limonene in the essential oil.

Methyl heptenone.—The fractions 5 and 6 indicated the presence of a ketone, which was identified to be methyl heptenone, because the physical constants of these

fractions coincided with those generally obtained for a genuine sample of methyl heptenone. The final identity was obtained by boiling the samples with a genuine sample when the boiling point remained undepressed.

The fraction 7 of Table III was mixed with the fraction 4 of Table II, and the mixture was distilled again at the ordinary pressure. After the distillation was over, the usual constants of each fraction were carefully determined. The results of these experiments are given in Table IV.

TABLE IV

Fraction	Boiling range	Specific Gravity at 30°C	Optical Rotation at 30°C	Refractive Index at 30°C	Volume (cc.)	Percentage
1.	200-204°C	0·8764	+7·8	1·444	9·7	24·8
2.	204-206°C	0·8762	+6·5	1·446	8·5	20·4
3.	206-208°C	0·8940	+5·1	1·447	8·9	23·7
4.	207-208°C	0·8960	−25·5	1·448	8·2	21·7
5.	Residue	...	...	...	2·8	7·4

Citronellal.—The fractions 1, 2 and 3 were combined and distilled again. As a result of this, the liquid distilled almost constantly at 205° C. The constants of this liquid were again determined and found to have specific gravity at 20° C : 0·8764 and refractive index at 20° C. : 1·4480. According to the analysis of E. G. Parry, the purest commercial sample has specific gravity of 0·873, and it is optically active to a very small extent only.

The identity of citronellal was further confirmed by shaking it with about thrice as much the quantity of a ten per cent. solution of mercuric sulphate in dilute sulphuric acid (25 per cent.); a fairly permanent bright yellow coloration was developed. (1)

The semi-carbazone of citronellal was also prepared. An alcoholic solution of the aldehyde was shaken with a solution of semi-carbazide hydrochloride and sodium acetate. The product thus obtained was crystallized from chloroform when the semi-carbazone was obtained in white laminæ melting at 81·5-82° C. (2 and 3). Thus, the identity of citronellal was finally established.

L-Menthone.—The fraction 4 was distilled again and boiled almost completely at 207° C. The constants were further determined and the following results were obtained : d20 : 0·8952 $(\alpha)^{D}20 = 28·4^{0}$, $n_{D}{}^{20}$, = 1·449. If we compare these constants with those determined in the Laboratories of Schimmel and Co. for *l*-menthone (d_{15}: 0·894-0·899 ; $(\alpha)_{D}$:—20°27′ to —26°10′ nD^{20} : 1·450 to 1·451 soluble in three volumes of 70 per cent. alcohol, d^{15} : 0·8971 ; $(\alpha)^{D}$: —26·10 to —29·11), we find

that the fraction is identical with *l*-menthone. In order to confirm the identity further, the following experiment was performed. A dilute alcoholic solution was prepared and condensed with hydroxylamine. The condensation took place readily and an oxime melting at 60·5° C. was obtained. Bechmann and Wallach (5 and 6) give the melting point of *l*-menthoxime as 60-61° C. The fraction was then mixed with a genuine sample of *l*-menthone and the mixed boiling point was the same as that of the original substance. This conclusively proved the identity of *l*-menthone.

The fractions 5 and 6 of Table II were taken, distilled again and their usual constants determined. The results are given in Table V.

TABLE V

Volume taken : 53·8 c.c.

Fraction	Boiling range	Specific Gravity	Optical Rotation	Refractive Index	Volume (c.c.)	Percentage
1.	200-223°C	0 8561	..	1·456	5·6	10·4
2.	223-226°C	0·8563	..	1·456	6·9	12·8
3.	226-228°C	0·8565	...	1·4570	7·2	13·5
4.	228-230°C	0·8790	...	1·4780	11·4	21·3
5.	230-240°C	0·9168	...	1·462	10·4	19·4
6.	240-245°C	0·9169	...	1·462	10·5	19·7
7.	Residue	0·9234	..	1·502	1·2	2·4

Citronellol.—The fractions 1—3 were distilled once again; the complete distillation took place at 225—226° C. The fraction so obtained was further investigated and all its constants were determined.

Specific gravity at 20°C.: 0·8564

Refractive index at 20°C.: 1·461

These constants agree very well with those found for citronellal. Citronellol from the Geranium oil has been found to possess the following constants:

B.P.: 225—226°C. (764·5 mm) d_{15}: 0·862—0·869 n_D^{20}: 1·459—1·463; soluble in about 14 volumes of 50 per cent alcohol and 3-4 volumes of 60 per cent alcohol.

It was then oxidised to citronellal following the acid phthalate Oxidation Method. Citronellal was converted to citronellyl-β-naphthocinchoninic acid melting at 2_5°C. Further confirmation was obtained by converting the citronellal so obtained into its semi-carbazone, which gave the correct melting point.

Geraniol.—The fraction 4 was identified to be geraniol. Schimmel & Co., quote the constant of this substance as follows: B.P. : 229—230° (75 mm.); d_{15}: 0·883—0·886; n_D^{20}: 1·476—1·478 soluble in 8—15 volumes of 50 per cent alcohol

and in 2·5—3·5 volumes of 60 per cent alcohol. This was oxidised to citral and then condensed with pyrotartaric acid and β-naphthylamine; the corresponding cinchoninic acid was obtained. The acid was found to melt at 201° C, which is about 3° higher than the melting point quoted by Doebner for the same acid (7). The final proof of identity was obtained by finding the mixed boiling point with a genuine sample of geraniol; the mixed melting point was the same as that of the specimen.

Geranyl acetate.—The fractions 5 and 6 of Table V were combined and distilled again. After the distillation, their constants were determined. The following results were obtained: Boiling range: 242-244°C. Specific gravity at 20°C. = 0·9170, n_D^{20}: 1·462. Bertram and Gildemeister quote the constants of the substance as follows: B. P.: 242-245° C. with decomposition (764 mm.) d_{15}: 0·9174, n_D^{15}: 1·4628. Schimmel and Co. observe $d_{15} = 0{\cdot}910 - 0{\cdot}917$, $(\alpha)_D$: $-0n_D^{20}$: 1·462 to 1·466, soluble in 7-10 volumes of 70 per cent alcohol. The mixed melting point of this fraction with a genuine sample remained undepressed.

Residue.- The residue of Table V was combined with that of Table IV. It became thick on account of the slight decomposition that had taken place during the course of distillation. The constants were found to be: Boiling range: 250-270°C. Specific gravity at 20° C.: 0·9456 n_D^{20}: 1·511. All these indicate the presence of sesquiterpenes. But no definite sesquiterpene could be identified, because no suitable derivatives could be prepared. Hence, the residue remained almost unidentified.

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STUDIES ON THE INDIAN SPECIES OF THE GENUS *CATHÆMASIA* LOOSS WITH DISCUSSION ON THE FAMILY *CATHÆMASIDÆ* FUHRMANN, 1929.

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SUMMARY

Three new species of the genus *Cathæmasia* Looss are described and their relationships discussed. The family Cathæmasidæ Fuhrmann is reduced to the rank of a subfamily in the family Echinostomatidæ Poche.

So far no forms belonging to the genus *Cathæmasia* Looss are described from India or, as a matter of fact, from the East. In this paper the three species of the genus, *viz.*, *Cathæmasia orientalis* n. sp., *Cathæmasia indicus* n. sp. and *Cathæmasia mehrai* n. sp., obtained from the storks and Indian black Ibis from the United Provinces (India), are described.

The family Cathæmasidæ was created by Fuhrmann in 1929 to include the genus *Cathæmasia* Looss and *Mehlisia* Johnston. It appears that *Cathæmasia*, which is closely related to the Echinostomatidæ, cannot be separated from the latter family. We have, therefore, dropped the family Cathæmasidæ and reduced it to the rank of a subfamily under the Echinostomatidæ.

Cathæmasia orientalis n. sp.

These parasites were obtained on several occasions from the œsophagus of the white-necked stork, *Dissoura episcopa episcopa*, shot or examined alive, from Allahabad and neighbouring districts. The number of parasites obtained from each host was 2—32 and, in all, about half a dozen hosts were examined for the purpose. The parasites were kept alive in normal salt solution at room temperature from one to three days. In the living condition the parasites are dull red or flesh-coloured and elongated with pointed anterior and rounded posterior ends, and have a thick muscular body. The pre-acetabular part of the body is capable of much contraction and extension. The cuticle of the ventral surface of the body is covered with scales, which, towards its lateral margins, become elongated with backwardly directed pointed ends like the spines. The scales and the spines are much more numerous anteriorly and gradually diminish in number from in front behind, disappearing

entirely a little distance in front of the hinder end. They are entirely absent on the dorsal surface of the body.

The cerebral commissure lies behind the oral sucker between it and the pharynx It gives off posteriorly two long thick nerves, which run laterally closely inside the cæca up to the posterior end. The excretory pore lies terminally in a depression, which appears as a notch at the hinder end of the body. The excretory bladder is Y-shaped, consisting of a short main stem, which bifurcates into the long cornua just behind the posterior testis. The cornua give off here and there a small number of lateral branches. A fairly large number of deeply staining gland cells lie in the anterior part of the body surrounding the oral sucker and in two indefinite lateral rows on either side of the œsophagus up to the intestinal bifurcation. The body measures in fixed specimens 7—13 mm. in length and 2·15—3·95 mm. in maximum breadth, which lies in the posterior third of the body. The collar, which is not visible in the entire mounts, seems to be absent. A few collar spines of a very small size are, however, indistinctly seen, but one cannot be certain about their presence unless some more living specimens are examined.

The oral sucker is sub-terminal facing ventrally and measuring 0·8 × 0·9 mm. in size. The acetabulum, which lies at about one third body length from the anterior end, is larger and more muscular than the oral sucker, measuring 1·2 mm. in diameter. The ratio in the size of the oral and the ventral suckers is about 3:4. The prepharynx has 0·35 mm. length and 0·55 mm. breadth. The muscular pharynx is spherical, measuring 0·55 mm. in diameter. The moderately long œsophagus has a wavy outline and measures 1·6 mm. in length and 0·3 mm. in maximum breadth, which lies anteriorly just behind the pharynx. The intestinal bifurcation lies at 3·45 mm. from the anterior end. The intestinal cæca are slightly undulating and without outgrowths terminating near the hinder end at 0·2 mm distance in front of it.

The testes are nearly equal, broader than long, deeply lobed consisting of 4—5 prominent, rounded or nearly ovoid lobes. They are situated, closely behind one another, near the hinder end of the body, measuring 1·25 mm. in length and 1·625 mm. in maximum breadth. The vasa efferentia arise as thin narrow tubes from the middle of the anterior margins of the testes and unite at the base of the cirrus sac to form the vas deferens, which at once becomes enlarged into the vesicula seminalis. The thin-walled cirrus sac of nearly subspherical form and 0·7 × 0·675 mm. size lies median a little in front of the acetabulum, at 0·8 mm. distance behind the intestinal bifurcation. It includes within it a large coiled vesicula seminalis with broad posterior and narrow anterior parts, followed by a tubular pars prostatica surrounded by the prostate gland cells and eversible cylindrical, muscular cirrus which, when protruded, measures 0·75 mm. in length and 0·156 mm. in breadth. The cirrus in most of the specimens in my possession lies coiled and unprotruded within the cirrus

sac The genital opening lies median on the ventral surface at almost half the distance between the intestinal bifurcation and the acetabulum.

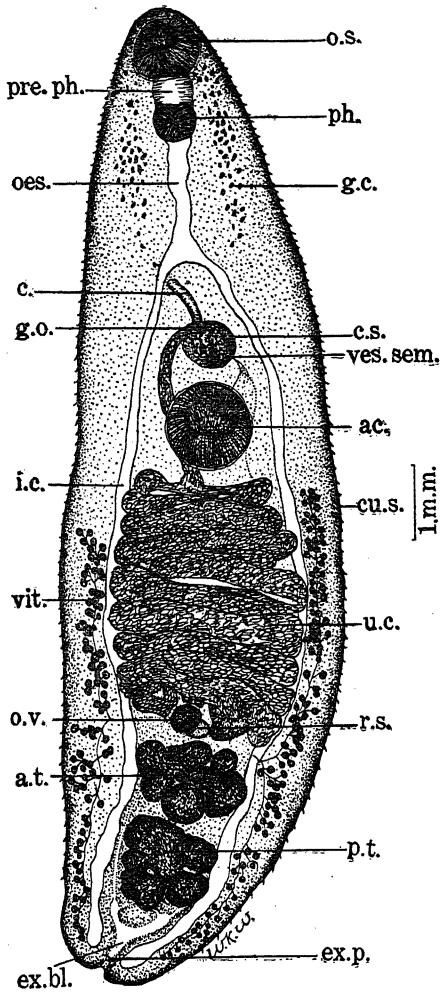

Fig. 1.

Ventral view of *C. orientalis* n. sp.

Explanation of Lettering

ac. acetabulum ; *a. t.* anterior testis ; *c.* cirrus ; *co.* collar ; *c. s.* cirrus sac ; *c. sp.* collar spines ; *cu. s.* cutaneous spines ; *ex. bl* excretory bladder ; *ex. p.* excretory pore ; *g. c.* gland cells ; *g. o.* genital opening ; *i. c.* intestinal caecum ; *m.* metraterm ; *oes.* oesophagus ; *o. s.* oral sucker ; *ov.* ovary ; *ph.* pharynx ; *p. p.* pars prostatica ; *pre. ph.* prepharynx ; *p.t.* posterior testis ; *r. s.* receptaculum seminis ; *u. c.* uterine convolutions ; *ves. sem.* vesicula seminalis ; *vit.* vitellaria.

The small ovary is rounded or oval, entire and situated median or slightly to the right side, a little in front of the anterior testis, at about half the distance between the acetabulum and the hinder end, measuring 0·4 × 0·36 mm. in size. A small subspherical receptaculum seminis of 0·35 × 0·25 mm. size lies inside and slightly behind the ovary partly overlapping its inner margin. The Laurer's canal passes behind the receptaculum seminis to open to the exterior in the mid-dorsal line. The uterus is large, thin-walled, much-coiled and filled with innumerable ova, which in the terminal coils contain well-developed miracidia having eye spots. The uterine coils are intercæcal partly overlapping the cæca and transversely arranged close to one another, occupying almost the entire space behind the acetabulum up to the anterior testis. Terminally the uterus passes into the muscular metraterm, which runs in the median line dorsally to the acetabulum to open to the exterior at the genital opening. The eggs are oval with thin yellowish brown shells, measuring 0·096 mm. in length and 0·04 mm. in greatest breadth.

The vitellaria of restricted extent are situated laterally, confined to the edges of the body, mainly outside the intestinal cæca and partly overlapping them. They are composed of moderate-sized follicles of about 0·076 mm. diameter, commencing a little behind the ventral sucker and terminating a little in front of the blind ends of the intestinal cæca near the hinder end. In some specimens they commence a little farther forwards, *i.e.*, from near the posterior margin of the acetabulum, but not at the same level. The transverse vitelline ducts arise at about the level of the ovary and unite in the median line to form the yolk reservoir over the shell gland complex situated internally to the ovary just in front of and partly overlapped by the receptaculum seminis.

The genus *Cathæmasia* Lss., as known at present, includes only three species *C. hians* (Rud.), *C. spectabilis* Odhner, 1926 and *C. famelica* Odhner, 1926, all recorded from Europe. *C. fodicans* Braun, 1902 based on a single specimen in the Viana Museum is considered by Odhner (1926) to be a synonym of *C. hians*. *C. orientalis* n. sp. resembles *C. hians* (Rud.) in the size of the body, in the ventral surface being covered with spines throughout the body length, and in the size of the suckers, pharynx and ova, but differs in the greater length of the œsophagus, shape of the testes, size of the ovary—which is smaller in *hians*—and the vitellaria commencing from behind the posterior margin of the acetabulum and not from the anterior margin of the latter as in *hians*. The new species resembles *C. famelica* in the size of the body, size of the suckers, in the extent of the body bearing cutaneous spines and extent of the vitellaria, but it differs in the shape of the testes, which are lobed in the new species and strongly branched into long, narrow, tubular outgrowths in *famelica*, in the presence of the receptaculum seminis, in the shape of the cirrus sac and in the size of the ovary and ova. From *C. spectabilis* it differs in almost all the important features of anatomy.

Cathæmasia indicus n. sp.

These parasites were obtained from the buccal and nasal cavities, œsophagus and proventriculus of the painted stork, *Ibis leucocephalus leucocephalus*, available at Allahabad and other places in U.P. The number of parasites obtained from each host was 2—6.

The parasites are some what pinkish in colour, muscular and elongated, with more or less rounded ends. The pre-acetabular part of the body is capable of much contraction and extension.

The cuticle of the ventral surface of the body is covered with scales almost throughout the entire length, but the lateral spines do not extend behind the acetabulum. The scales or spines are absent on the dorsal side

The body measures, in fixed specimens, 8·9-10·9 mm. in length and 3·2-3·95 mm. in maximum breadth, which lies just behind the acetabulum at about the middle of the body length The collar and collar spines are absent.

The excretory pore lies terminally at the hinder end of the body, which is not notched as in the previous species The Y-shaped excretory bladder has shorter stem than in *C. orientalis* n. sp., because the testes are situated quite near the hinder end in this species. The cornua give off a few lateral branches.

The sub-terminal oral sucker measures 0·85 × 0·95 mm. in size The acetabulum lies at about one third body length from the anterior end, is larger and more muscular than the oral sucker, measuring 1·4 mm. in diemeter. The ratio in the size of the oral and the ventral suckers is about 9 : 14. The prepharynx, 0·1 mm. long and 0·4 mm. broad, is smaller than in *C. orientalis* n. sp. The muscular pharynx is spherical, measuring 0·45 mm. in diameter. The œsophagus has a wavy outline and measures 1 mm. in length and 0·35 mm. in maximum breadth. The intestinal bifurcation lies at 2·375 mm. from the anterior end. The intestinal caeca, provided with small outgrowths towards the body wall, terminate near the hinder end at 0·2 mm distance in front of it.

The testes are more or less deeply branched into tubular outgrowths and situated closely behind each other near the hinder end of the body, measuring 0·8 × 1·4 mm. and 1 × 1·1 mm. respectively. The vasa efferentia are long and arise from the middle of the anterior margins of the testes as in the previous species. The cirrus sac is thin-walled, pear-shaped, 1·4 × 0·65 mm. in size and situated obliquely in the median line, 3·5 mm. distance behind the intestinal bifurcation. The coiled vesicula seminalis is followed by the long tubular pars prostatica, which is surrounded by the prostate gland cells. The eversible cirrus is conical and when protruded measures 0·45 × 0·275 mm. in size. The genital opening lies median or slightly to one side on the ventral surface nearer the intestinal bifurcation than the acetabulum.

The small, oval or oblong ovary of 0·55 × 0·33 mm size lies transversely in the median line a little in front of the anterior testis and at about one third post-acetabular length of the body from the hinder end. The receptaculum seminis,

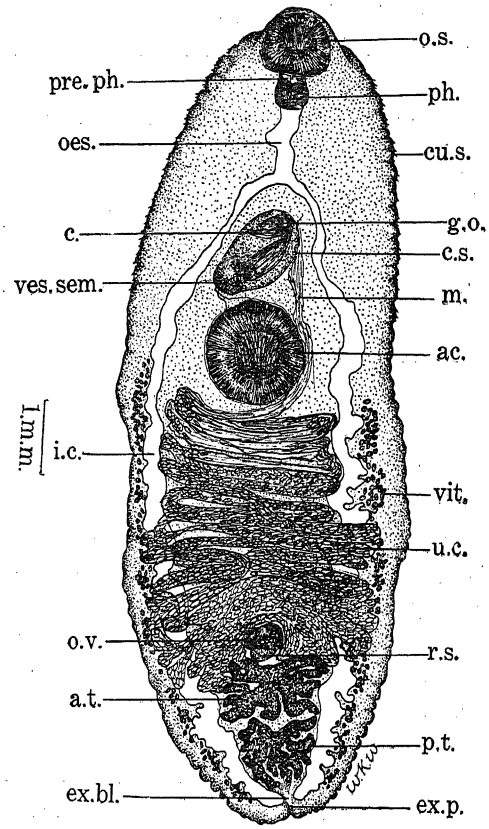

Fig. 2.

Ventral view of *C. indicus* n. sp.

(Lettering as in Fig. 1.)

0·5 × 0·33 mm. in size is subspherical and lies partly overlapping and partly behind the posterior margin of the ovary. The Laurer's canal is present. The numerous uterine convolutions are transversely arranged, closely pressed against one another filling almost the entire post-acetabular region right up to the anterior testis, overlapping the intestinal caeca and surrounding the ovary anteriorly and laterally. The distal half of the uterine coils are filled with eggs containing well-developed miracidia with black eye spots. The muscular metraterm runs to the left side of the acetabulum to open to the exterior at the genital pore. The eggs are oval with thin yellowish brown shells and measure, 0·056-0·08 × 0·026-0·04 mm. in size.

The vitellaria extend from about the middle of the acetabulum or near its posterior margin, but not at the same level, the right usually commencing a little in front of the left one, and terminate just in front of the hinder end. The follicles are oval in shape and smaller than those of *C. orientalis* n. sp. The transverse vitelline ducts arise at about the level of the ovary and unite in the median line to form the yolk reservoir over the shell gland complex.

C. indicus n. sp. resembles *C. famelica* Odhner in the length of the body and in the cutaneous scales extending over the entire length, in the caeca being provided with small outgrowths, to a certain extent in the size of the suckers and in the size of the ova, but it differs in the shape of the testes which are not so much branched as in *famelica* and, further, the branches of the testes are not so long and narrow as in the latter species. It also differs in the breadth of the body shape and position of the cirrus sac and position of the ovary.

From *C. orientalis* n. sp. it can be easily distinguished on account of the ratio in the size of the suckers, intestinal caeca being provided with small saccular outgrowths, shape of the testes, which are lobed and not branched in *orientalis*, shape and position of the ovary and the cirrus sac and smaller size of the vitelline follicles

Cathaemasia mehrai n. sp.

Dr. Mehra gave me for study about a dozen specimens in entire mounts belonging to this species, which were obtained from the oesophagus and the small intestine of the Indian black Ibis, *Pseudibis papillosus*.

The body measures 7-9·2 mm. in length and 3-3·8 mm. in maximum breadth attained at about two thirds of the body length from the anterior end and possesses at the anterior end a small, rudimentary collar armed with small spines at the ventro-lateral corners. The collar spines are 12 in number on each side and measure 0·048 × 0·016 mm. in size. The cuticle of the entire ventral surface is covered with small backwardly pointed spines of 0·04 × 0·012 mm. size. The cutaneous scales as present in the previous species are here replaced by spines.

The excretory system resembles that of *C. orientalis* n. sp.

The oral sucker measures 0·7 mm. in diameter. The acetabulum is larger measuring 1 mm. in diameter and lies at about one third body length from the anterior end. The ratio in the size of the oral and ventral suckers is 7 : 10. The thin-walled prepharynx measures 0·2 mm. long and 0·3 mm. broad. The pharynx is almost spherical, measuring 0·5 mm. in diameter. The oesophagus, 0·76 mm. long and 0·225 mm. broad, has crenated margins. The intestinal bifurcation lies at 2·25 mm. from the anterior end. The intestinal caeca are provided with small outgrowths towards the body wall and terminate near the hinder end at 0·22 mm. distance in front of it.

The testes, 0·9 × 1·25 mm. in size, show in their shape an intermediate condition between that of *C. orientalis* n. sp and *C. indicus* n. sp. They are more deeply lobed and the number of lobes is larger than in *C. orientalis* n. sp., but do not show the same branched appearance as in *C. indicus* n. sp. The lobes are broader and somewhat saccular in appearance and not tubular and narrower as in *C. orientalis* n. sp. The thin-walled, oval, cirrus sac though it resembles that of *C. indicus* n. sp. in shape and position is smaller, measuring 0·6 × 0·5 mm. in size. The large coiled vesicula seminalis and the pars prostatica enclosed in the cirrus sac present the

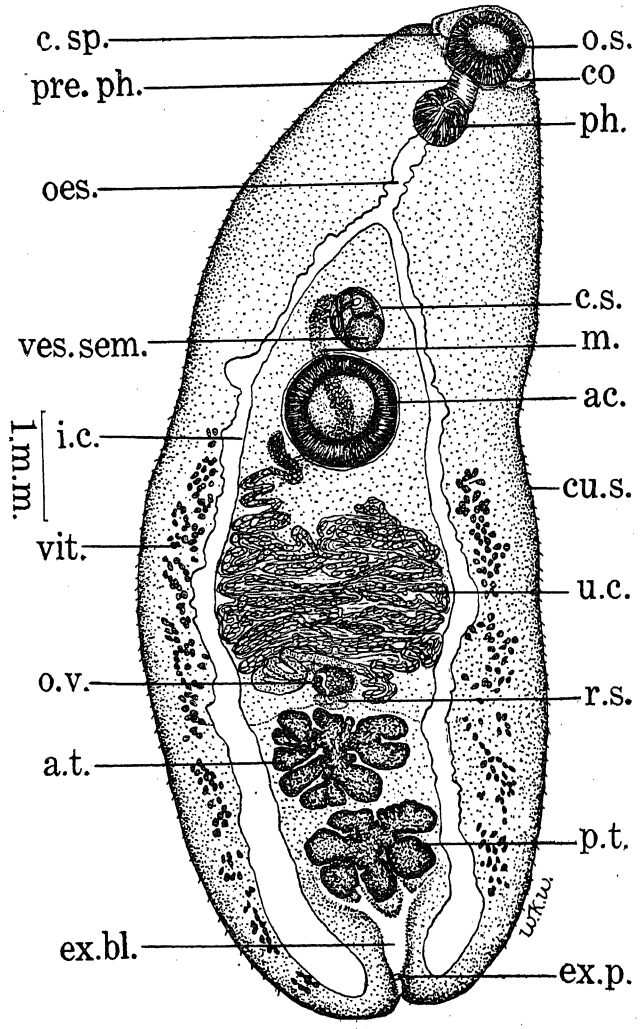

Fig. 3.
Ventral view of *C. mehrai* n. sp
(Lettering as in Fig. 1)

same appearance as in *C. orentalis* n. sp. The cirrus when not protruded lies coiled upon itself inside the cirrus sac. The genital opening lies median almost midway between the intestinal bifurcation and the acetabulum.

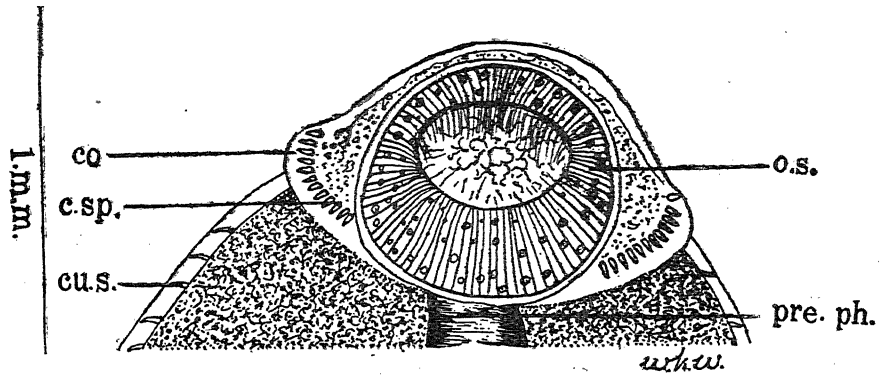

Fig. 4.

Anterior end of *C. mehrai* n. sp. showing the collar armed with spines.

(Lettering as in Fig. 1)

The ovary is somewhat oval or transversely elongated, measuring 0·38 × 0·25 mm. in size. It lies closely in front of the anterior testis at about half-way between the acetabulum and the hinder end as in *C. orientalis* n. sp. The receptaculum seminis of 0·35 × 0·15 mm. size also occupies the same position as in the other species. The Laurer's canal is present. The transversely arranged uterine convolutions occupy almost the entire intercaecal space between the acetabulum and the posterior margin of the ovary. The eggs are oval, yellowish brown and 0·056-0·076 × 0·03-0·032 mm. in size. They contain well developed miracidia with black eye spots in the distal half of the uterus.

The vitellaria occupy the usual position as in the other species, extending from the posterior margin of the acetabulum to the hinder end of the body. The vitelline follicles measure 0·07 × 0·04 mm. in size.

C. mehrai n. sp. resembles *C. famelica* Odhner in the size of the body, size of the suckers and ova, but it differs from it in the presence of the small vestigial collar armed with spines at its ventro-lateral corners, size of the pharynx and the shape of the testes.

C. mehrai n. sp resembles *C. orientalis* n. sp. in the length of the body, size of the suckers and pharynx, position and shape of the ovary, cirrus sac and ova. But it differs on account of the presence of the small collar armed with spines, length of the oesophagus, the intestinal caeca being provided with small outgrowths and shape of the testes, which, as has been mentioned above, show an intermediate condition between those of *C. orientalis* n sp. and *C. indicus* n. sp.

Remarks on the family Cathaemasidae Fuhrmann

The family Cathaemasidae as created by Fuhrmann in 1929 for the genus *Cathaemasia* Looss and *Mehlisia* Johnston resembles closely the family Echinostomatidae in its internal organisation as has been mentioned by Fuhrmann himself. The absence of the collar in this family, is not to be considered as a contant feature of the family, as in *Cathaemasia mehrai* n. sp. a distinct though vestigial collar armed with collar spines is present. The only obvious point of difference from the Echinostomatidae is the absence of the lateral branches in the short median stem of the Y-shaped excretory bladder. In our opinion this is not of such importance as to justify the creation of the family Cathaemasidae. We, therefore, reduce the latter family to the rank of a subfamily Cathaemasinae in the family Echinostomatidae.

I have great pleasure in expressing my indebtedness to Dr. H. R. Mehra, under whom this work was carried out, for his valuable guidance. I am also very grateful to him for going through the manuscript and making necessary corrections

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ANNOTATED LIST OF THF HELMINTHS RECORDED FROM DOMESTICATED ANIMALS OF BURMA, PART III NEMATODA AND ACANTHOCEPHALA

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Introduction

The nematode fauna of Burma, especially parasitic forms from domesticated animals has been left untouched An attempt is made in this paper to furnish an up-to-date list of nematodes and acanthocephala from domesticated animals, based chiefly on personal observations. The importance of nematodes in relation to the diseases that they produce is well known. Though in Burma very little weight is attached to the subject, the value of the study of nematodes in connection with the diseases they cause has been acknowledged in many countries on account of its growing importance in medical science, veterinary and agriculture, so much so that it has formed a subject by itself known as 'nematology'. The physiology of nematodes and the host immunity are some of the recent problems practically neglected in India and Burma and except for a few plant infesting forms such as *Anguillulina angusta* (Butler 1913) from rice, *Anguillulina tritici* (Steinbuch 1799) from wheat, *Anguillulina similis* (Cobb 1893) and *Anguillulina pratensis* (de Man 1881) chiefly from coffee and *Heterodera marioni* (Cornu 1879) from roots of tomato and brinjal very little is known about plant infesting or soil forms from these two countries. The author has endeavoured to study some of the soil forms, especially those obtained from paddy soil, and has been struck by the large variety of forms present. He has further endeavoured to study material he has obtained from slaughter houses or from animals dissected in the laboratory of the Institute. In doing so an important part of thes ubject (nematodes from Equidæ) has unavoidably, for lack of facilities been omitted, those few forms here inserted being based on specimens provided by the kindness of Mr. R. Clarke Glover, M.R.C.V.S., in his private capacity. The author fully realises how poor has been his attempt compared to the exhaustive nature of the subject and for whatever little he has been able to do, he expresses his sincere thanks to Mr. R. Clarke Glover, Prof. F. J. Meggitt and Dr. H. R. Mehra, without whose help it would have been impossible for the author to complete the present work.

SYSTEMATIC

Class NEMATODA Rudolphi 1808.
Order Ascaroidea Railliet and Henry 1915.
Family Ascaridæ Cobbold 1864.
Sub-family Ascarinæ Travassos 1913.
Ascaris Linnæus 1758.
Ascaris lumbricoides Linnæus 1758

Host: Pig.

Location: Intestine.

Common in pigs and also observed several times in human stools: twice in public latrine of Scot Market, twice in railway latrines in Rangoon and Insein and once in a third class railway carriage. Besides these the author obtained once a number of worms passed out by an Indian typist. A number of worms from the intestine of a suckling pig were also obtained, probably a case of prenatal infection.

The infective eggs of various ascarids hatch in the intestine of many vertebrates: the larvæ migrate through the lungs, but do not grow adult in the intestine if the host is unsuitable. Ortlepp has shown that eggs of ascarids from snakes will hatch in the intestine of mice and migration through the lungs takes place even in these animals. In this way infective eggs of the pig ascaris, though it belongs to a different strain, may be dangerous to man and other animals.

How much the use of night soil as fertilizer in fields contributes to ascaris infection in man is a question on which opinions seem to differ. The author has very little personal knowledge about rural conditions in Burma, but what he has seen in many provinces of India he believes it improbable that fields in which field crops or vegetables are grown contribute much towards the spread of infection, though they cannot totally be ignored. That the defecation habits of young children facilitates the spread of the disease has been emphasised by various authors, and the conditions existing in many parts of India confirm this view. Children in villages and in many important towns of India defecate in the open courtyards of their respective dwellings or along the sides of the streets, places which also serve as their playgrounds. Similar observations on this line have been made by Winfield (1937) in young children of pre-school age in west Shantung China. In many cases the stools remain for long periods before they are collected by some member of the family and thrown into a field or the latrine; in many cases they are eaten by dogs. However, whether the stool be thrown into the latrine or eaten, in almost every case some of it is left in direct contact with the earth and which, each day being supplemented by fresh deposits, provides a permanent and fertile source of infection Wherever chickens occur they also consume a part of the stool, either from the courtyard or from the latrine. Dogs that devour human faeces pass 52—76%

viable eggs (Otto, Cort and Keller 1931) and chickens 16–40 %: when these animals in their turn defecate in the courtyard or on the streets of villages and towns, they thus materially contribute in the distribution of the worm. Eggs, which thus are present in large numbers in the courtyard soil or in road dust, may be blown by wind on vegetables, rice, bread or other eatables or may be carried by the filthy hands of young children playing in the dirt of the courtyard or streets of villages and towns. The carelessness of these children in touching their mouths with hands or in taking their meals without first washing has been noticed by all, and that this ignorance of hygiene contributes a large share towards the spread of infection has been pointed out by many workers. Various other factors have been brought forward to explain the transmission of this parasite. Water has been mentioned by some, though this appears to be of little importance to India or Burma. Recently, Lane (1934) has suggested that air-borne eggs from latrines may be inhaled and they may hatch in the lungs thus producing infection. How far Lane's theory is applicable the author has no knowledge, but on the surface it appears untenable. The important role played by house-fly (*Musca domestica*) in the distribution of helminth infection in places where human faeces are accessible to it has recently been shown by Pod 'yapol' skaya and Gnedina (1934). Apart from the carrying of eggs on the wings and legs, house-flies were found to deposit in their droppings those helminth eggs that were easy for them to swallow. The investigator further showed experimentally that droppings of blow-flies (*Calliphora erythrocephala*) contained most of the helminth eggs *Ascaris lumbricoides*, *Enterobius vermicularis*, *Diphyllobothrium latum*) with which they experimented, and in their observations under natural conditions in Dagheston, Russia, helminth eggs occurred in the specks deposited by the flies on a number of glass slides placed in the hall and dining room of a slaughter-house and in the kitchen and dining room of a railway restaurant, where flies swarmed in enormous numbers. How far flies help in dessimination of helminth diseases in tropical countries like India and Burma where they swarm in large numbers we have no knowledge but in the light of recent work by Pod 'yapol' skaya and Gnedina it seems probable that they play an important role.

The worms from pig have been used extensively for class work ever since Prof. Meggitt's assumption of office as Professor of Biology in the Rangoon University (1922) though Bhattacharjee (1937) claims to be the first to record its occurrence in pigs in Burma.

Ascaris Vitulorum Gœze 1782

Host: Cattle.

Location: Intestine.

First recorded by Bhattacharjee (1937, 87).

Ascaris equorum Goeze 1782.

Host: Horse.

Location: Intestine.

First recorded by Bhattacharjee (1937, 88).

Toxocara Stiles 1905.

Toxocara canis (Werner 1782).

Host: Dog.

Location: Intestine.

Not so common as in many parts of India. Obtained twice from the vomits of dogs, probably due to heavy infection Prenatal infection of pups in the uterus of a pregnant bitch has been observed in one case. First recorded by Bhattacharjee (1937, 88).

Toxocara elephantis (Rudolphi 1819)*

Host: Elephant.

Location: Bile-ducts.

The first helminth recorded from the elephant. Rudolphi regarded this worm as a strongyle. Diesing (1851) examined Rudolphi's material in the Vienna Museum, originally collected from the bile-ducts of an Indian elephant at Geneva, and pointed out that the worm was an ascarid, a diagnosis confirmed by Drasche (1882). The only record of this parasite from Burma is that by Gaiger (1915).

Subfamily Ascaridiinæ Travassos 1919.

Ascaridia Dujardin 1845.

Ascaridia galli (Schrank 1788)

Host: Fowl.

Location: Intestine.

Rare. The life-history of the parasite has been elucidated by Ackert (1931, 360). Infection takes place by ingestion of the eggs with food or water Earthworms may ingest the eggs and so, when swallowed by the birds, transmit the infection mechanically. The larvæ normally develop into adults in the intestine and only exceptionally does a larva migrate through the lungs as in the case of Ascaris and Toxocara. First record of this parasite from Burma.

*Not found by author.

Ascaridia columbae (Gmelin 1790).

Host: Pigeon.

Location: Intestine.

Rare. Life-history probably similar to that of *Ascaridia galli*. First record of this parasite from Burma.

Family Oxyuridæ Cobbold 1864.

Subfamily Oxyurinæ Hall 1916.

Oxyuris Rudolphi 1803

Oxyuris equi (Schrank 1788).

Host: Horse.

Location: Colon and cæcum.

Eggs are laid in clusters on the skin in the perianal region by the crawling females and there quickly develop with warmth. Irritation of the anus, due to the passage of the worms or to some irritant secreted by them, cause the horse to rub its tail and buttocks against walls, etc., often producing external lacerations. The presence of the parasite in the intestine may cause digestive disturbance or, more rarely, anæmia Eggs are ingested by the host with food or water and afterwards hatch in the small intestine. Recorded previously by Gaiger (1910) and Bhattacharjee (1937, 88).

Family Heterakidae Railliet and Henry 1914.

Subfamily Heterakinae Railliet and Henry 1912.

Heterakis Dujardin 1845.

Heterakis gallinae (Gmelin 1790).

Host: Fowl.

Location: Cæcum.

Occasional. The embryo hatches in the intestine and develops into adult without migrating into the tissues First record of this parasite from Burma.

Heterakis beramporia Lane 1914.

Host: Fowl.

Location: Caecum.

Rare Life-history probably similar to *Heterakis gallinae*. First record of this parasite from Burma.

Order Strongyloidea Weinland 1858.

Family Stronglidae Baird 1853.

Subfamily Strongylinae Railliet 1893.

Strongylus Muller 1780.

Subgenus *Strongylus* Railliet 1923.

Strongylus (Strongylus) equinus Muller 1780.

Host: Horse.

Location: Cæcum, colon.

Red when alive, usually found firmly attached to wall of gut. Infective larvae formed in the fermenting horse manure are very resistant to unfavourable conditions and are probably capable of maintaining themselves on pastures for long periods, when they may be scattered by rain or wind reaching places far from their original site. After being ingested with the food or drinking water by a suitable horse, they cast off their sheaths and penetrate into the mucosa of the intestine. They are carried away by the lymph and blood to various organs and tissues, such as the liver, pancreas, spleen, lungs, kidneys from which many fail to get back to the gut. The rest of the life-cycle is not well known except that the young worms return to the intestine and become adult. Possibly, as in other cases, the larvae migrate up the trachea and are swallowed when they reach the pharynx. Strongylidosis is a widespread disease in horses and is frequently mistaken for infectious anaemia or swamp fever, the common symptoms being diarrhea, weakness and other digestive disturbances.

Strongylus vulgaris, a form found in several parts of India and in all probability in Burma also, is specially injurious since its immature form settles in certain arteries (usually anterior mesenteric) which supply blood to the gut. Thickening and stretching of the arterial wall produces 'aneurisms' (dilatation of the blood vessel through a heavy internal deposit of fibrin) which may sometimes attain the size of a child's head. This interferes with the circulation, resulting in a diminished blood supply to the large intestine and ending in colic, twist or intussusception. Sometimes fibrin deposited in the anaeurism becomes detached and may be carried in the circulation to a terminal position of an artery, acting there as a plug which, when formed in a hind leg, may cause a form of intermittent lameness. Recorded previously by several authors from Burma.

Subgenus *Decrusia* Lane 1914.

Strongylus Decrusia additicius, Railliet, Henry and Bauche 1914.

Host: Elephant.

Location: Large intestine.

First recorded by the author in a report of the Institute to the Veterinary Department (Smith 1933).

Equinurbia Lane 1914.

Equinurbia sipunculiformis (Baird 1859)

Host: Elephant.

Location: Cæcum

The number of rays in the leaf-crowns, as counted by the author does not agree with that given by Lane (1914). The external leaf-crown consists approximately of 138 rays (Lane 168), out of which 46 are long Lane 56) and 92 small (Lane 112). External to longer rays, but lying in apposition to them and posterior to terminations of shorter rays appear structures with blunt ends, indications of which can be seen in Lane's figures: whether they are independent rays or part of the longer rays seen as an optical illusion it is impossible to ascertain In all probability they are a third kind Internal leaf-crown bears 92 small rays (Lane 112) and arranged in a row at base of mouth collar. Recorded previously by several authors from Burma.

Choniangium Railliet, Henry, and Bauche 1914.

Choniangium epistomum (Pianna, in Pianna and Stazzi 1900)

Host: Elephant.

Location: Cæcum.

First recorded by the author in a report of the Institute to the Veterinary Department. (Smith 1933).

Subfamily Trichoneminae Railliet 1916.

The nematodes of elephants and rhinoceros included in this subfamily comprise a number of genera two of which *Murshidia* and *Amira* have been separated and two subfamilies Murshidiinae Witenberg 1925 and Amirinæ Neveu-Lemaire 1924 have been created for their reception. The author agrees with Baylis and Yorke and Maplestone and believes that there is no justification for their separation from Trichoneminae though very recently Westhuysen (1938) has again tried to establish a case for this classification.

The genus *Pteridopharynx* Lane 1921 has been shown to be a synonym of *Murshidia* Lane 1914 by Yorke and Maplestone (1926), Baylis (1936), and Westhysen (1938), though Neveu-Lemaire (1928) contends that some of the characters in *Pteridopharynx* are so prominent that merely with the naked eye parasites of the two genera can be isolated from a mixed collection. This no doubt holds good for some of the species where the most salient characters, as pointed out by Neveu-Lemaire (1928), are the differences noticable in the posterior extremity of both the male and the female. Though in some species of *Murshidia* the bursa is very short and wide

and the posterior attenuation of the body from the vulval region is gradual whereas in some *Pteridopharynx* the striking feature is the long dorsal lobe of the bursa and the close proximity of the anus to vulva which results in the sudden constriction of the female tail appearing to the naked eye as a spinous process projecting from the posterior end of the body, yet these peculiarities, which appear so striking in the type species, on closer examination appear to merge into one another in other species of the genera. For example in *Pteridopharynx* the distance between vulva and anus ranges from 0·075—0·4 (see *P. omoensis* Neveu-Lemaire 1924 and *P. nereu-lemaire* Witenberg (1925) whereas in *Murshidia* it ranges from 0·5—0·8 (see *M. linstowi* Khalil 1922 and *M. falcifera* (Cobbold 1882). From these figures it appears that there is a continuity in the range from 0·075—0·8 and hence no importance can be attached to this character. Similarly it can also be shown in the character of the bursa that the complete or partial fusion of the external branches of the dorsal ray or their complete separation is a matter of degree and no reliance can be placed on this character as well. In view of these points the author considers *Pteridopharynx* Lane 1921 as identical with *Murshidia* Lane 1914. *Pterygopharynx* is obviously a wrong quotation by Witenberg (1925) for *Pteridopharynx*, Lane 1921, as no genus *Pterygopharynx* Lane 1914 exists. In *Memphisia* Khalil 1922 the only distinguishing character is the presence of a ring-shaped cuticular collar which, however, is little developed in *Memphisia aziza* Khalil 1922, the other characters being more or less same as in *Murshidia*: the former is therefore considered identical with the latter. *Henryella* Neveu-Lemaire 1924 closely resembles *Murshidia* and is separated from it by slight differences in the bursal rays, differences so slight that the two genera cannot be considered as separate. Thus *Pteridopharynx* Lane 1921, *Pterygopharynr* Witenberg 1925, *Memphisia* Khalil 1922 and *Henryella* Neveu Lemaire 1924 are all synonyms of *Murshidia* Lane 1914.

Murshidia Lane 1914.

Murshidia falcifera (Cobbold 1882).

Host: Elephant.

Location: Cæcum and large intestine

More common than the other two Indian species. Probably feeds on bacteria and fermented vegetable matter in the host, as particles of straw have been found on many occasions in the gut of the parasite. Recorded previously by several authors from Burma.

All measurements in millimetres.

Murshidia murshida Lane 1914.

Host: Elephant.

Location: Cæcum and large intestine.

First recorded by the author in a report of the Institute to the Veterinary Department (Smith 1933).

Murshidia indica (Ware 1924).

Host: Elephant

Location: Cæcum and large intestine.

First recorded by the author in a report of the Institute to the Veterinary Department (Smith 1933)

Quilonia Lane 1914.

Quilonia renniei (Railliet, Henry and Joyeux 1913).

Host: Elephant.

Location: Cæcum and large intestine.

More abundant than any other nematode parasites of elephants. Like *Murshidia* fragments of straw have been found several times in the gut of the parasite. Recorded previously by several authors from Burma.

Quilonia travancra Lane 1914.

Host: Elephant.

Location: Cæcum and large intestine.

First recorded by the author in a report of the Institute to the Veterinary Department (Smith 1933.)

Subfamily Oesophagostominæ Railliet 1915

Oesophagostomum Molin 1861.

Oesophagostomum dentatum (Rudolphi 1803)

Host: Pig.

Location: Rectum.

Obtained on several occasions from the slaughter house. First report of the parasite from Burma

Oesophagostomum quadrispinulatum (Marcone 1901).

Host: Pig.

Location: Rectum.

First report of the parasite from Burma.

Oesophagostomum columbianum (Curtice 1890)

Host: Goat, sheep, cattle.
Location: Large intestine.

Reported by several authors from Burma.

Oesophagostomum venulosum (Rudolphi 1809)

Host: Goat, sheep.
Location: Large intestine.

Reported previously by Bhattacharjee (1937, 91).

Bosicola Sandground 1929.

Bosicola radiatus (Rudolphi 1803) *

Host: Cattle, buffalo.
Location: Large intestine.
Reported by Bhattacharjee (1937, 91).

Subfamily Syngaminæ Baylis and Daubney 1926.

Syngamus v. Siebold 1836.

Syngamus laryngeus Railliet 1899*

Host: Buffalo, cattle.
Location: Larynx.

Reported by Bhattacharjee (1937, 92)

Family Ancylostomidae (Looss 1905) Lane 1917.

Sub-family Ancylostominae (Looss 1905) Stephens 1916

Ancylostoma (Dubini 1843) Creplin 1845.

Ancylostoma caninum (Ercolani 1859) v. Linstow 1899

Host: Dog.

Location: Intestine.

Frequent. The number of eggs produced per day by each hookworm has been the subject of a considerable amount of speculation and investigation in recent years. McCoy (1931, 101) concludes that the normal egg production of *A. caninum* in dogs is 16,000 per day per female. Infection in dogs is also known experimentally through oral administration of larvae: those eventually pass into the blood before they come to rest in the intestine.

Recent work on hookworms has shown the possibility of acquired immunity in the host. McCoy (1931) showed that when puppies were given repeated doses of hookworm lavrae over a considerable period of time, the effects gradually accumulated, causing a severe anaemia. In a few cases the animals succumbed to the effect of the worms and died. In most cases they survived after a period of crisis. Such animals were then, in spite of further exposure to infection, resistant to any further development of worms in their intestines, the effect being produced by a host reaction to repeated doses of infection. It may, however, be pointed out that, though under existing natural conditions this is the normal effect, in experimental conditions the result in many cases may be fatal on account of the disturbance of the protective mechanism in the host by an overwhelming heavy dose of parasites. In certain cases the resistance of a dog against hookworms is broken down after being subjected for a considerable period to a deficient diet. Foster and Cort (1931, 1932) showed that dogs, which, on account of age and previous infections, had developed such a resistance to *A. caninum* that even enormous doses of larvae failed to produce infestation, became, after subjection for a considerable period to a deficient diet, as susceptible as when first infected as puppies.

On return to an adequate diet, however, they quickly rejected the parasites and again acquired immunity; on the other hand, when continued on the poor diet and repeatedly infected, death from hookworm finally resulted.

The relation of domesticated animals to the spread of hookworm disease is a question of vital importance. It is well known that in tropical countries like India, pigs, dogs, goats, cattle and buffaloes (and incidentally also rats) habitually devour humam faeces, often as a regular article of diet. In many places in India Chandler (1929), in the course of his hookworm campaign, had difficulty in finding any stool in places used daily by dozens of men, due to the habitual ingestion of the defaecated products by pigs, dogs or cattle in the early mornings. Calmette and Breton (1905) showed that humam hookworm eggs would pass out uninjured in dogs. Ackert and Payne (1922) showed that hookworm eggs would likewise pass uninjured through pigs, and develop in cultures, the per cent of developing larvae being larger than in the original faeces. Ackert (1922) showed that hookworm eggs ingested by chickens are to a large extent destroyed, probably by the grinding action on the less resistant egg shell in the gizzard, but that a certain percentage pass through unharmed, and proceed with their development. Chandler (1924) confirmed these results with respects to the dogs and pigs and also showed that the eggs pass uninjured through rats. There is strong reason to suspect that the eggs survive passing through cattle and buffaloes. The author has no knowledge if direct experiments have ever been performed to determine the fate of hookworm eggs in these animals. Chandler (1929) has observed however that in places where the stools are habitually eaten by cattle and buffaloes the degree of human infestation is lower than would normally be

expected; moreover he failed to find by the D. C. F. method any hookworm eggs in a considerable number of cattle and buffalo stools from areas where human fæces were usually eaten by these animals, nor did he succeed in obtaining any hookwarm larvae from cultures made from these cattle stools. In the coal mines of Bengal he (1926) observed that—although conditions were such as to prevent dessication, and there were no scarabaeid beetles or ants to carry away the fæces or to mix them with the substratum, and no domestic animals to devour them—nevertheless the stools were disappearing at a rapid rate. Investigation showed that large cockroaches (*Periplanata americana*) were devouring the faeces, in most places as rapidly as they were deposited. Later, by direct experiment, it was demonstrated that the vast majority of eggs eaten by cockroaches are destroyed in the proventriculus and not more than one per cent viable eggs succeed in passing through the alimentary canal. Cockroaches are thus very useful scavengers, and succeed in destroying the great majority of eggs which they devour. On this ground Chandler (1926, 12) has advocated the destruction of rats, a source of menace to those useful roaches especially in coal mines. It is probable that hookworm eggs likewise are extensively destroyed in the proventriculus of scarabaeid beetles. Cultures of faeces invaded by maggots produce relatively few larvæ, but the fate of eggs devoured by maggots has not been directly investigated. The important role played by the housefly (*Musca domestica*) in the distribution of helminth infection has been discussed under *Ascaris lumbricoides*.

Ancylostoma braziliense (Gomez de Faria 1910)

Host: Dog, cat.

Location: Intestine.

Occasional. Always found in dog as a secondary infection to *A. caninum*. It is interesting to note that it is present in carnivores as well as in man. First record of this parasite from Burma.

Subfamily Necatorinae Lane 1917.

Globocephalus Molin 1861

Globocephalus connorfilii Lane 1922.

Host: Pig.

Location: Intestine.

Obtained on a few occasions from the slaughter house. First record of this parasite from Burma.

Globocephalus samœnsis Lane 1922.

Host: Pig.

Location: Intestine.

Obtained on a few occasions from the slaughter house. First record of this parasite from Burma.

Bunostomum Railliet 1902

Bunostomum trigonocephalum (Rudolphi 1802).

Host: Goat

Location: Intestine.

Obtained once from the slaughter house. First record of this parasite from Burma.

Grammocephalus Railliet and Henry 1910.

The genus, as has been pointed out by other authors, is of marked interest on account of certain peculiarities not observed in other forms of *Strongyloidea*: these are the presence of an intestinal diverticulum (a structure present only in some genera of Ascaroidea), strong teeth near the middle of buccal capsule (seldom in strongyloidea), and the smaller size of the female, a phenomenon quite the reverse to the general condition in nematodes.

Grammocephalus varedatus Lane 1921.

Host: Elephant

Location: Bileducts.

Reported previously by several authors from Burma.

Bathmostomum Railliet and Henry 1909.

Bathmostomum sangeri (Cobbold 1879).

Host: Elephant.

Location: Cæcum.

Recorded previously by Gaiger (1910, 1915).

Family Trichostrongylidæ Leiper 1912.

Subfamily Trichostrongylinæ Leiper 1912.

Hæmonchus Cobb 1898.

Hæmonchus contortus (Rudolphi 1803).

Host: Goat, sheep, cattle.

Location: Stomach.

Reported previously by Bhattacharjee (1930).

Mecistocirrus Railliet and Henry 1912.

Mecistocirrus digitatus (v. Linstow 1906).

Host: Cattle.
Location: Stomach.

Reported previously by Bhattacharjee (1937, 92).

Family Metastrongylidæ Leiper 1908.

Dictyocaulus Railliet and Henry 1907.

Dictyocaulus filaria (Rudolphi 1809).*

Host: Goat.
Location: Bronchi.

Recorded by Giles (1892)

Dictyocaulus viviparus (Bloch 1782).*

Host: Cattle.
Location: Bronchi.

Recorded by Bhattacharjee (1930).

Order Spiruroidea Railliet and Henry 1915.

Family Spiruridæ Oerley 1885.

Subfamily Spirurinæ Railliet 1915.

Spirocerca Railliet and Henry 1911.

Spirocerca lupi (Rudolphi 1809)

Host: Dog.
Location: Free in œsophagus or in tumours on its wall.

Recorded previously by Bhattacharjee (1930).

Habronema Diesing 1861.

Habronema muscæ (Carter 1861).

Host: Horse.

Location; Stomach.

The presence of these worms in horses is very difficult to ascertain by any definite symptoms and it is usually detected by examination of a stomach wash of an infected horse. The worms are injurious as they penetrate the stomach wall and form tumours which, once formed, interfere to a great extent with the proper functioning of the stomach and in severe cases may cause obstruction to food.

Another injury is produced by the larvæ which enter cuts or bruises on the skin and produce summer sores, known in India as 'Bursati'. The seasonal occurrence of the disease corresponds to the prevalence of flies, which feed on the sores and carry the larvæ. These latter escape from the proboscis of the fly and live for a time in the wounds, producing irritation. These sores persist until the flies become rare and for the protection of wounds from the flies the use of oils such as pine-tar oil have been recommended by veterinarians. Recorded previously by Bhattacharjee (1930).

Draschia Chitwood and Wehr 1934.

Draschia megastoma (Rudolphi 1819).*

Host: Horse.

Location: Stomach, usually in tumours.

Reported by Bhattacharjee (1937, 93).

Parabronema Baylis 1921.

Parabronema indicum Baylis 1921.

Host: Elephant.

Location: In tumour on stomach wall.

First report of this parasite from Burma

Parabronema smithii (Cobbold 1882).

Host: Elephant.

Location: In tumour on stomach wall.

Recorded previously by Bhattacharjee (1937, 93).

Subfamily Ascaropsinæ Alicata and Mc Intosh 1933

Ascarops v. Beneden 1873

Ascarops strongylina (Rudolphi 1819)

Host: Pig.

Location: Stomach and intestine.

Obtained on a few occasions from the slaughter house. First record of this parasite from Burma.

Physocephalus Diesing 1861

Physocephalus sexalatus (Molin 1860)

Host: Pig.

Location: Stomach and intestine.

Obtained on a few occasions from the slaughter house. First record of this parasite from Burma.

Subfamily *Acuariinæ* Railliet, Henry and Sisoff 1912.

Acuaria Bremser 1811.

Acuaria (*Cheilospirura*) *hamulosa* (Diesing 1851).

Host: Fowl

Location: Between tunics of gizzard.

Previously reported by the author (1939, 323)

Family Physalopteridæ Leiper 1908

Subfamily Physalopterinæ Railliet 1893.

Physaloptera Rudolphi 1819.

Physaloptera præputalis v. Linstow 1889.

Host: Cat.

Location: Stomach.

Rare. Female can be distinguished from the male by the presence of a collar of cement at the region of the vulva. Nothing is yet known about the life-history of this parasite. The author in an attempt to trace its life-history has examined a number of fish and rats and though in the former, especially in *Clarias batrachus*, a common fresh-water fish of Rangoon, he has found the larvæ of *Gnathostoma spinigerum*, a parasite normally present in cats and other Felidæ of India and accidentally in man in Siam, Malay States, China, Japan and India, he found no clue to the larvæ of the present form until last year. A few of the toads (*Bufo melanostictus*) that were dissected for class work, carried in their stomach wall, pancreas, duodenum, urinary bladder and mesentary heavy infection of nematode cysts, which, on examination, were found to contain Physalopterid larvæ. On 11th September, 1939, approximately 200 cysts were fed with milk to a kitten born some days before and still feeding on milk. Fæcal examinations on successive days both before and after the infection gave negative results. The kitten was kept on a rice and milk diet for about four months and on 16th January, 1940, was dissected. Sixteen adult parasites (9 female and 7 male) of this species were obtained from the stomach in addition to four female *Ancylostoma braziliense* (Gomez de faria 1910) from the intestine. The cat was kept loose in the day in and near the house of the attendant and was allowed to play with a kitten of its age kept as control for the experiment, but at night was locked separately from the other in a cage. It was not possible to keep the cat day and night in the cage as complete captivity would probably have resulted in an early death. The kitten kept as a control under exactly the same conditions, was dissected on the following day. It was found to harbour five *Ancylostoma braziliense* (4 female and one male) in the intestine but no trace of any *Physaloptera* or other helminth was found in any part

of the body. Though there was a slight risk of the infection of the experimental cat being acquired from outside yet, considering the rarity with which these parasites occur in cats in Rangoon and the non-infection of the control kitten, it is more probable—though not proved beyond doubt—that the infection was the direct result of the experiment. Thus toads probably act as intermediate host.

The cysts are colourless, transparent, found in clusters and are, when developed, approximately 0·56 in dia. The larva is coiled inside and is, when developed, approximately 3 5 long, provided with well developed triangular lips, approximately 0 083 broad at the base and each bearing (*a*) prominent external tooth and (*b* three

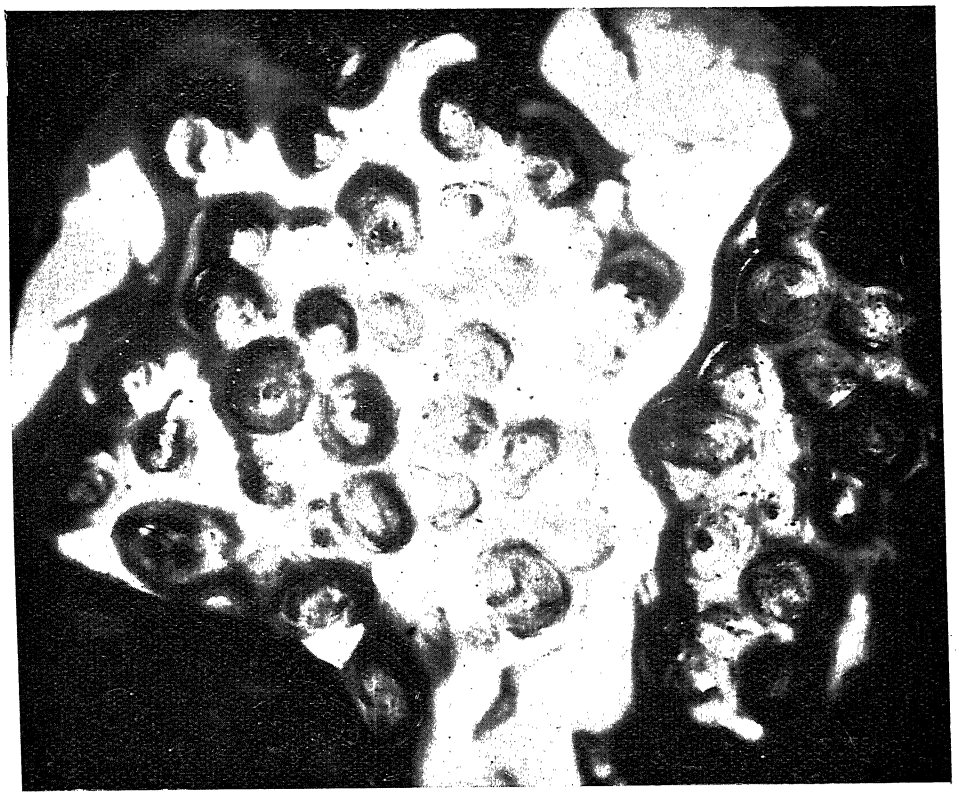

Fig. 1

Physaloptera praeputalis v. Linstow 1889 (Microphotograph of Cysts attached to Urinary bladder of *Bufo melanostictus*

internal teeth more or less of the same size as the external. Cuticle finely striated and in fresh specimens commencing posterior to lips: in fixed forms anterior part of body withdrawn and the cuticle investing it projects forwards as a sheath. In

Fig. 2
Physaloptera praeputalis v. Linstow 1889 (Microphotograph of a cyst enlarged)

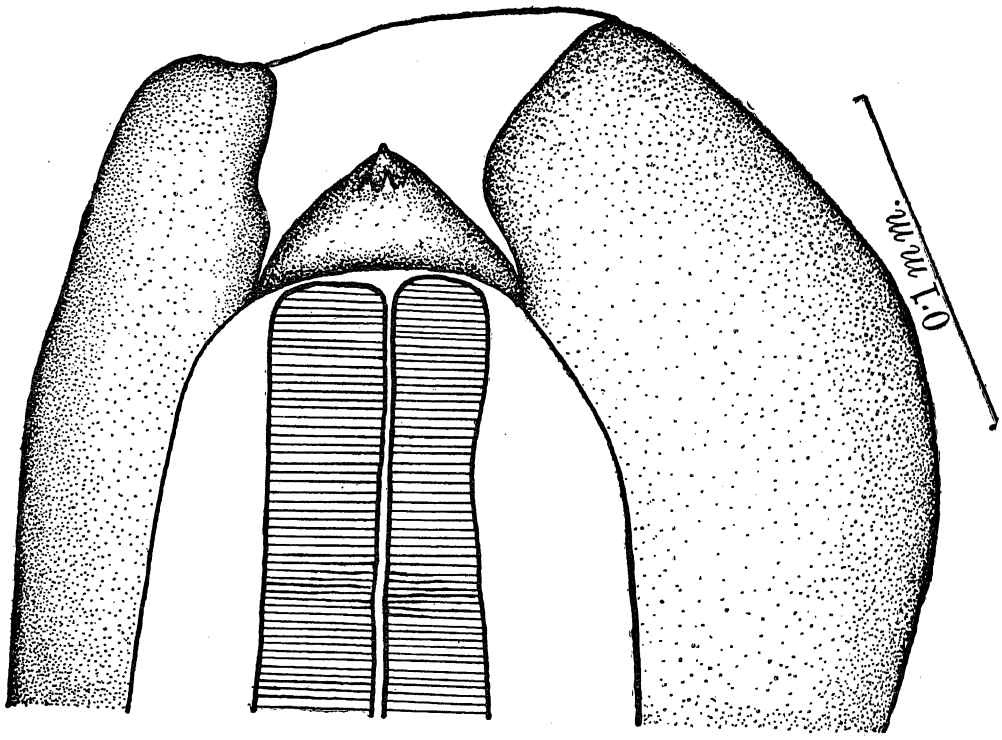

Fig. 3
Physaloptera praeputalis v. Linstow 1889 (larva-anterior end)

such retracted specimens the cephalic region is usually filled with dirt and food matter, probably exuded out of the mouth of the larva during fixation, and appears like a flattened knob. Oesophagus approximately 1·0 long, divided into a narrow anterior part and a comparatively broader and longer posterior part, 0·22 and 0·78 long respectively. Cervical papillæ at approximately 0·43 from anterior end. Tail approximately 0·12 long, truncate and ending bluntly. Sex organs not developed but males can be distinguished by the presence of a pair of spicules approximately 0·084 long and showing small difference in length. Adults reported previously by Baylis (1939) from a collection from Rangoon kept in the British Museum.

Family Thelaziidæ Railliet 1916.

Thelazia Bosc 1819.

Thelazia rhodesii (Desmarets 1828).

Host: Cattle, buffalo.
Location: Eye.

Recorded previously by Bhattacharjee (1937, 94)

Thelazia lacrymalis (Gurlt 1831)

Host: Horse.
Location: Eye.

Recorded by Bhattacharjee (1937, 94)

Thelazia callipeda Railliet and Henry

Host: Dog.
Location: Eye.

Common in hilly countries. Nothing is yet known about the life-history of the parasite but the following observations of Prof. Meggitt throw some light on the problem. The infection in dogs is correlated with their staying in hill stations as will be found in the following table:—

Date	Place	Height above sea-level	No. of dogs under observation	Result
1930: October	Maymyo	3557 ft.	2	Negative
1931: April-May	Thandaung	4308 ft.	7	Positive
1932: April-May	Kalaw	4338 ft.	8	Positive
1933: October	Maungmagaung	sea-level	3	Negative
1933: December	Thandaung	4308 ft.	3	Positive
1934: April-May	Toungyi	4875 ft.	3	Positive
1934: December	Thandaung	4308 ft.	3	Positive
1935: December	Thandaung	4308 ft.	1	Negative

All the above places agree in possessing large areas of wood and shrub, practically untouched, heavy rains and excessive drought at the proper seasons. Apart from Maungmagaun, all are cold at Christmas (10 degrees and under) and cool in the hot weather (approximately 65 degrees at night and 80 degrees during day). Professor Meggitt during his stay in the above places found biting flies at Maungmagaun, Thandaung, Kalaw and Toungyi which were absent from Maymyo. In addition, in the last three places were minute flies, apparently non-biting, which hovered consistently in front of the flies, endeavouring to settle on them. It appears plausible therefore to suggest that infection is conveyed by these flies. Recorded previously by Evans and Rennie (1910) and Bhattacharjee (1937, 94).

Order Filarioidea Weinland 1858.

Family Filariidæ Claus 1885.

Subfamily Filariinæ Stiles 1907.

Dirofilaria Railliet and Henry 1911.

Dirofilaria immitis (Leidy 1856).

Host: Dog.

Location: Heart, pulmonary artery and bronchi.

Obtained several times and often in dense masses. Recorded previously by several authors from Burma.

Onchocerca Diesing 1841

Onchocerca armillata Railliet and Henry 1909 *.

Host: Cattle, buffalo.

Location: Aorta (in nodules).

Recorded by Bhattacharjee (1937, 94).

Onchocerca gibsoni (Cleland and Johnston 1910) *.

Host: Cattle, buffalo.

Location: Subcutaneous tissue.

Bhattacharjee records it as *Onchocerca* sp. Sweet 1915. Sandground (1934) and Baylis (1939) have shown the identical nature of *Onchocerca indica* Sweet 1915 with the present form.

Setaria Viborg 1795.

Setaria equina (Abildgaard 1789).

Host: Horse.

Location: Peritoneal cavity, eye, thoracic cavity.

Recorded previously by several authors from Burma.

Setaria cervi (Rudolphi 1819).

Host: Cattle, buffalo.

Location: Peritoneal cavity.

Recorded previously by several authors from Burma. The worms described from India under the name *S. digitata* Railliet and Henry 1911, *S. labiato-papillosa* Railliet and Henry 1911, *S. cervi* Maplestone 1931 and *S. buxi* Bhalerao 1933 have all been shown by Baylis (1936) to be identical with the present form.

Setaria marshalli Boulenger 1921 *.

Host: Cattle.

Location: Peritoneal cavity.

A single female obtained in poor condition from Bassein was described by Boulenger under this name. It is doubtful whether this is a valid species.

Setaria bernardi Railliet and Henry 1911.

Host: Pig.

Location: Peritoneal cavity.

This species has been considered by Sandground (1933) as identical with *S. congolensis* Railliet and Henry 1911. The author has discussed the validity of the species in a separate paper First reported by the author (1939).

Order Trichinelloidea Hall 1916.

Family Trichinellidae Stiles and Crane 1910.

Subfamily Trichurinae Ransom 1911.

Trichuris Roederer 1761.

Trichuris trichiura (Linnaeus 1771).

Host: Pig.

Location: Cæcum.

First record of this parasite from Burma.

Trichuris globulosa (v. Linstow 1901).

Host: Sheep, goat.

Location: Cæcum.

First record of this parasite from Burma.

Trichuris ovis (Abildgaard 1795)

Host: Cattle, sheep and goat.

Location: Cæcum.

Reported previously by Bhattacharjee (1930).

Subfamily Capillariinae Railliet 1915.

Capillaria Zeder 1800

Capillaria anatis (Schrank 1790).

Host : Duck

Location : Crop and intestine.

A number of worms obtained on a few occasions. They agree in all essential characters except in the length of the spicule which is approximately 0·7 long (Orosz 1·3 – 1·8) and 0·013 broad. Spicule sheath 0·019 long, covered with minute spines. Posterior end of female blunt. Ova approximately 0·047 × 0·024.

Class Acanthocephala Rudolphi 1808.

Order Archiacanthocephala Meyer 1931.

Family Oligacanthorhynchidae Southwell and Macfie 1925.

Macracanthorhynchus Travassos 1917.

Macracanthorhynchus hirudinaceus (Pallas 1781).

Host : Pig.

Location : Intestine.

The parasite has been obtained on a number of occasions from the Kemmendine slaughter house. They are pale reddish in colour when alive and body usually more or less curved.

Family Moniliformidae van Cleave 1924.

Moniliformis Travassos 1915.

Moniliformis moniliformis (Bremser 1811)*.

Host : Cat.

Location : Intestine.

Once obtained by Bhalerao from a Rangoon cat. As has been suggested by Bhalerao, it is probable that the cat acquired the infection by feeding upon an infected rat, in which it is a common parasite of the intestine.

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